Broadwater Power Project Jetty Replacement, Erosion Control, and Canal Intake Gates

Preliminary Engineering Report

Toston Dam/Broadwater-Missouri Irrigation System

Broadwater County, MT

August 20, 2021

Contents

Tables

Figures

Appendices

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Executive Summary

Project Summary

This Preliminary Engineering Report (PER) assesses alternatives to address issues for three project components at the Broadwater Project on the Missouri River near Toston Montana. The three components are:

1. Jetty
2. Irrigation headworks gates
3. Bank erosion

Background

The Broadwater Project is a 9.66 Megawatt (MW), run-of-river hydroelectric project owned by the State of Montana DNRC. It is operated by the State Water Projects Bureau (SWPB). The project consists of a concrete gravity dam 51.5 feet high and 705 feet long which was originally constructed in 1940 as an irrigation diversion structure by the State Water Conservation Board as the Broadwater-Missouri Diversion Project.

Between 1987 and 1989, a Powerhouse was constructed in the left abutment that contains a single, pit-Kaplan hydroelectric generating unit. In addition, inflatable rubber bladder flashboards were installed to control the upstream water surface elevation. The reservoir level is maintained at 3952.6 +/- 0.6 feet year-round.

The original irrigation diversion structure was demolished and reconstructed concurrent with the addition of the Powerhouse between 1987 and 1989. Water from the reservoir is diverted into the Broadwater-Missouri Canal through an irrigation headgate structure (headworks) to the left of the Powerhouse (looking downstream). The headworks structure consists of four steel slide gates, each four feet wide by seven feet, three inches high. Three of the gates are manually operated; one is electrically operated. Each gate is protected by an individual trash rack installed vertically in stoplog guides located immediately upstream of the slide gates.

In 2000, a rock embankment jetty was placed between the irrigation canal headworks and turbine intakes. It extends out from the dam approximately 160 feet into the reservoir to separate the irrigation canal flow from the Powerhouse flow. The purpose of the structure was to reduce the amount of floating debris reaching the irrigation canal intake, for which it has generally been effective at accomplishing. However, the rock comprising the jetty is slowly settling and/or shedding rock requiring the periodic addition of new rock to the top of the jetty. Some of the rocks being shed appear at the Powerhouse intake. Past replacement of rock on the jetty has not been a successful long-term solution as indicated by the continued need for rock replacement.

The BLM Upper Toston Recreation Area is located immediately upstream of the Broadwater Project. It has three campsites, parking, a latrine, and a boat launch with a floating dock. Portions of the riverbank between the recreation areas and the Toston Dam and Broadwater-Missouri Canal Headworks have been slowly eroding. It is suspected that a combination of boat wakes and the channeled flow to the Powerhouse and headworks are facilitating the erosion.

Based on the history presented above, the SWPB identified the jetty, slide gates, and bank stabilization as project components to be assessed through an alternatives analysis to evaluate potential alternatives for mitigating associated deficiencies for each as follows:

1. Jetty: The existing jetty is exhibiting signs of instability and settlement and is shedding jetty material towards the Powerhouse intake.
2. Slide Gates: The existing gates are reaching the end of their design life and leak when fully closed which impacts operations.
3. Bank Stabilization: Instability and erosion of the bank for the upstream recreational area was identified.

Process

A preliminary alternatives matrix was prepared for each of the project components, including the Jetty, Slide Gates, and Bank Stabilization. The process was used to develop a wide range of alternatives which were then scored based on a standard set of criteria (i.e. modified pairwise ranking). Strengths and risks for each alternative were considered as well as how each addressed project goals and objectives. The goal was to rank the alternatives through a numerical process such that the range of alternatives could be culled to a reasonable number and to document that the discarded alternatives had been considered. DNRC comments were then used to finalize alternatives for further analysis.

Alternatives retained/developed for further consideration are presented in this PER. Alternative development is semi-conceptual in nature and are based on similar projects and typical wall and floor thicknesses, pile sizes, common gate sizes, etc. Following alternatives development, a pairwise ranking was then completed to compare alternatives based on established criteria. A Draft PER was delivered to DNRC for review and comment. Based on that conversation, the Box Culvert option was added and minor clarifications to other portions of the report

Results and Conclusions

Jetty

The DNRC has identified a number of deficiencies with the existing jetty which are contributing to increased floating debris accumulation at the irrigation headworks (headworks), excess sediment (sand) being delivered into the canal and impacting operations, as well as contributing to rock material shedding towards the Powerhouse intake. Conceptual design alternatives selected for further development include:

- No Action
- Floating Debris Barrier
- Floating Breakwater
- Riprap Jetty (Jetty Reconstruction)
- Flexible Intermediate Bulk Container (FIBC) Jetty (Jetty Reconstruction)
- Grout Jetty (Jetty Reconstruction)

- Sheet Pile Jetty Structure (Jetty Reconstruction)
- Trash Rake System
- Box Culvert
- Relocate Irrigation Headworks Upstream
- Relocate Irrigation Headworks Downstream

For each alternative, the PER presents: a discussion of the alternative, advantages, disadvantages, opinion of probable construction cost; life cycle analysis; permitting requirements and discussion of other items relevant to the specific alternative.

Slide Gates

The existing slide gates are reaching the end of their design life and leak when fully closed which impacts operations. Conceptual design alternatives selected for further development include:

- No Action
- Replace Slide Gates

Bank Stabilization

Bank stabilization options for the Bureau of Land Management (BLM) Upper Toston Recreation Area were developed, described and inserted into a pairwise ranking system during the early stages of this project. The goal of the initial assessment was to develop a wide range of alternatives for presentation to stakeholders. Eleven alternatives were developed and ranked based on eight criteria. The pairwise assessment allowed a quantitative analysis of the alternatives to determine the top three alternatives for future consideration.

BLM reviewed the options and selected their preference based on success at similar sites for past projects, precluding the need to develop additional alternatives further.

Recommendations

The pairwise matrix for jetty replacement was updated based on SWPB comments. The resulting top three alternatives are:

1. Box Culvert
2. Riprap Jetty
3. FIBC/Grout Jetty

Upon closer examination it can be seen that the conceptual cost estimates for a 50-year life cycle are: $2.38M, $1.63M, and $1.30/$1.32M, respectively. However, due primarily to simpler design and construction complexity and impacts to the dam/hydropower intake risk, the **Box Culvert** is the recommended alternative. It should be noted that minor adjustments to the weighted scoring system changes the preferred alternative.

It is recommended that the existing **slide gates be replaced in kind** as they have reached the end of their design life. Final gate design would be based on the jetty alternative selected and effectiveness of the alternative at controlling floating debris and sediment transport and deposition, with different types and configurations of gates considered as applicable.

Bank stabilization at the BLM Upper Toston Recreation Area would incorporate BLM preference with site specific details added. In general, the recommended bank stabilization will include a rock base capped with an aggregate mix then topped with a growth media. Coir logs and/or coir fabric would be utilized, and the site would be revegetated.

1 Introduction

1.1 Purpose and Introduction

Montana Department of Natural Resources and Conservation (DNRC) contracted with HDR Engineering (HDR) to perform engineering design and construction support at the Broadwater Project (known locally as the Toston Dam) on the Missouri River near Toston, MT. The project includes engineering, permitting, and construction oversight to remove an existing rock jetty originally constructed to reduce debris loading on the Broadwater-Missouri Canal intakes, provide an alternate method to reduce the debris loading on the intakes, install erosion control measures along the bank at the U.S. Bureau of Land Management (BLM) Upper Toston Recreation Site just upstream of Toston Dam and assess the existing irrigation canal headworks control gates and propose alternatives.

This Preliminary Engineering Report (PER) presents alternatives considered and evaluation of short-list alternatives for each of the three project components:

- Jetty
- Irrigation headworks gates
- Bank erosion

1.2 Project Location

The Broadwater Project is located on the Missouri River, near the town of Toston, Montana. The site is approximately 20 river miles downstream of the headwaters of the Missouri and about 20 river miles upstream from Canyon Ferry Reservoir. The project location is shown in Figure 1-1 with site components shown in Figure 1-2

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Figure 1-1 Project Location

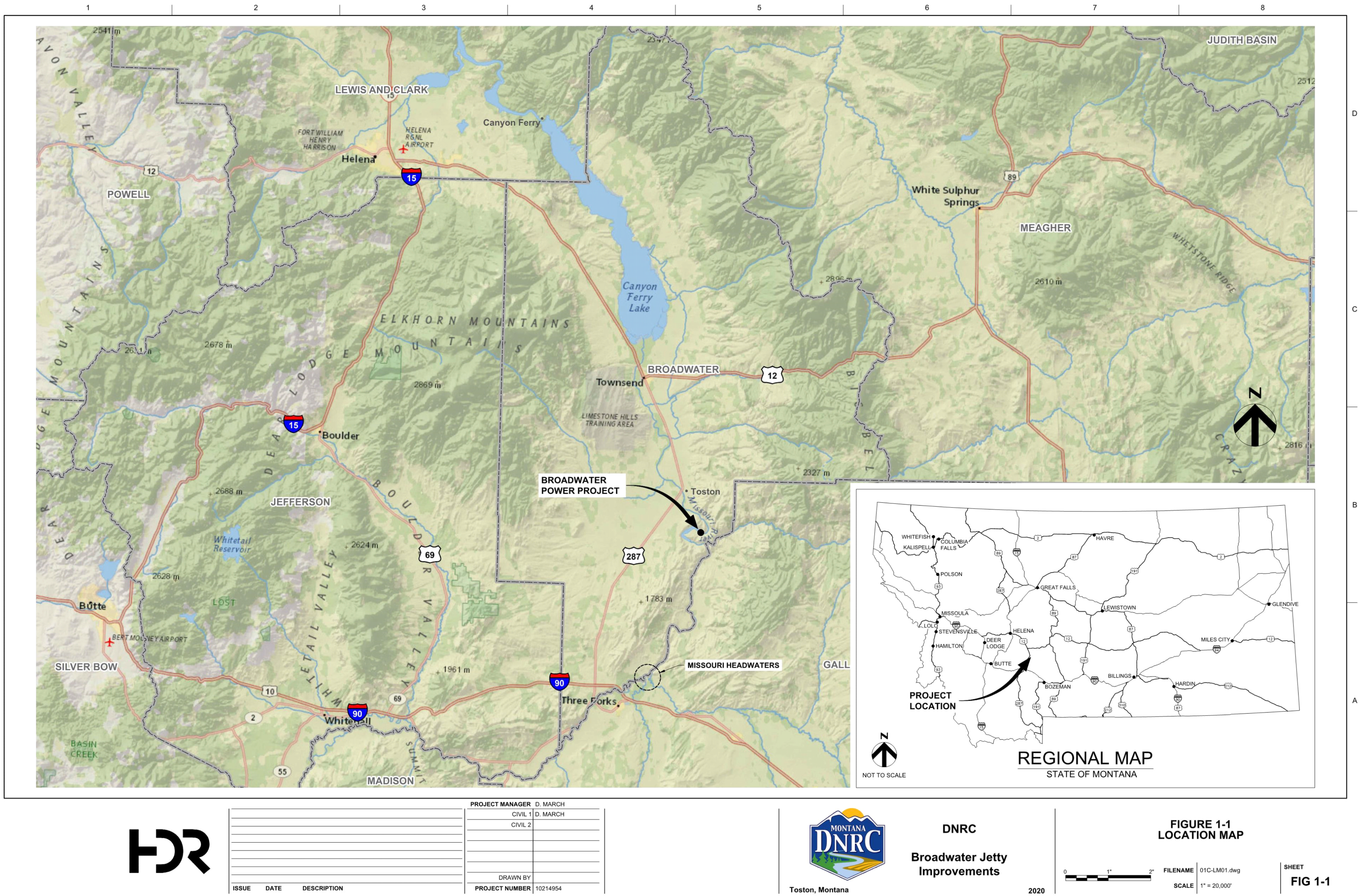


Figure 1-2. Site Map.

1.3 Background Information

1.3.1 Toston Dam and Powerhouse

The Broadwater Project is a 9.66 Megawatt (MW), run-of-river hydroelectric project owned by the State of Montana DNRC. It is operated by the State Water Projects Bureau (SWPB). The project consists of a concrete gravity dam 51.5 feet high and 705 feet long which was originally constructed in 1940 as an irrigation diversion structure by the State Water Conservation Board as the Broadwater-Missouri Diversion Project. The dam originally impounded approximately 4,100 acre-feet of water and covered approximately 327 acres in the upstream reservoir at normal full pool. A 2018 bathymetric survey showed the reservoir area to be approximately 275 acres and the volume to be approximately 2400 acre-feet. Water stored in the reservoir is used for irrigation, power generation, and recreational uses.

Between 1987 and 1989, a Powerhouse was constructed in the left abutment that contains a single, pit-Kaplan hydroelectric generating unit. In addition, inflatable rubber bladder flashboards were installed to control the upstream water surface elevation. The reservoir level is maintained at 3952.6 +/- 0.6 feet year-round.

When originally constructed, the Powerhouse included a floating debris barrier intended to protect the irrigation canal intake. The floating debris barrier was located at the approximate location of the existing jetty and comprised of floating foam-filled booms and chain link fence mesh draped down below the booms. As originally installed, the floating debris barrier had a number of issues related largely to the collection of debris on the barrier and challenges removing collected debris. In addition, the DNRC indicated that a major problem with the system occurred during “load rejection” events, during which submerged suspended debris accumulated and impinged on the Powerhouse intake trash rack would release when the turbine tripped and stopped taking in water. The debris mass would then often stay suspended and work its way under the floating debris barrier and impinge on the canal intake where removal was difficult.

More recent rehabilitation projects include the installation of a new automated trash rake system for the Powerhouse intake in 2002, as well as replacement of the inflatable rubber bladders in 2014.

1.3.2 Broadwater-Missouri Main Canal

The Toston Dam was originally constructed as an irrigation diversion structure to provide irrigation water for the downstream Broadwater-Missouri Canal. Downstream irrigation water user contracts total 42,000 acre-feet of irrigation water. The original irrigation diversion structure was demolished and reconstructed concurrent with the addition of the Powerhouse between 1987 and 1989.

Water from the reservoir is diverted into the Broadwater-Missouri Canal through an irrigation headgate structure (headworks) to the left of the Powerhouse (looking downstream). The headworks structure consists of four steel slide gates, each four feet wide by seven feet, three inches high. Three of the gates are manually operated; one is electrically operated. Each gate is protected by an individual trash rack installed vertically in stoplog guides located immediately upstream of the slide gates. Immediately downstream of the headworks, a concrete transition section conveys the flow to a box culvert section ten feet wide by seven feet high, and approximately 400 feet long. The box culvert discharges through an outlet transition section into the main Broadwater-Missouri Canal. Downstream of the outlet transition section, the DNRC constructed a new measurement station in 2020 consisting of a 15x15 foot long concrete open box configuration with vertical walls. The canal is operated by the Broadwater-Missouri Water Users Association (BMWUA). The irrigation canal has a capacity of 342 cubic feet per second (cfs) immediately downstream of the headworks. There are no wasteways in the vicinity of the dam through which canal flow could be diverted to the river.

1.3.3 Diversion Jetty

In 2000, a rock embankment jetty was placed between the irrigation canal headworks and turbine intakes. It extends out from the dam approximately 160 feet into the reservoir to separate the irrigation canal flow from the Powerhouse flow. The purpose of the structure was to reduce the amount of floating debris reaching the irrigation canal intake, for which it has generally been effective at accomplishing. However, the rock comprising the jetty is slowly settling and/or shedding rock requiring the periodic addition of new rock to the top of the jetty. Some of the rocks being shed appear at the Powerhouse intake. Past replacement of rock on the jetty has not been a successful long-term solution as indicated by the continued need for rock replacement.

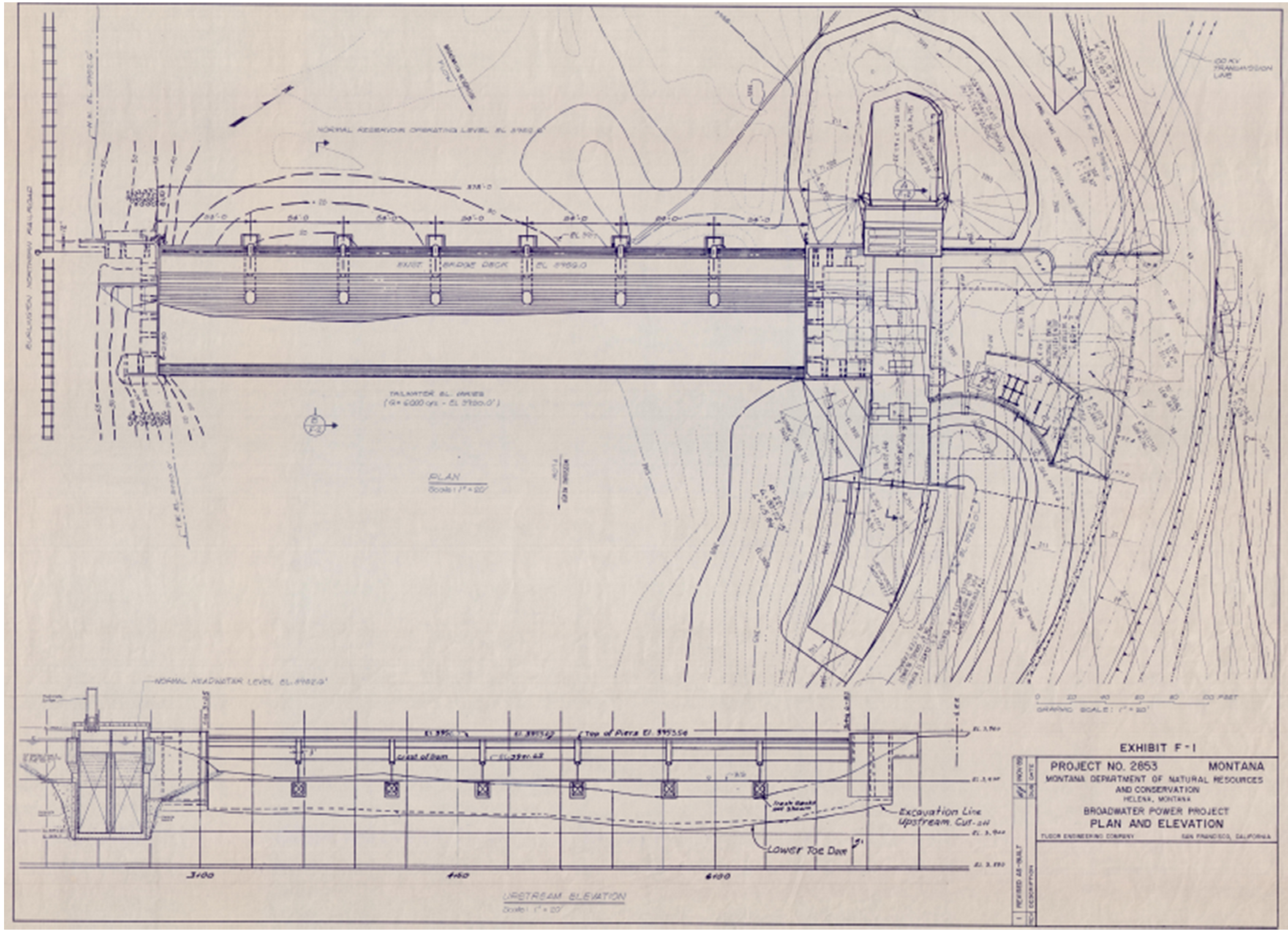
As-built drawings were provided by the DNRC for the Powerhouse intake, jetty, and headworks as shown in Figure 1-3. The Powerhouse intake as-built drawings identified a concrete apron with vertical concrete walls extending approximately 50 feet from front of the intake with an invert elevation of 3897.3 feet and wall elevation of approximately 3928.0 feet at the upstream face of the dam. Reinforced shotcrete placed at a 0.5:1 slope was identified extending above the walls, above which 2.5 feet of Class II riprap at a 2:1 slope was placed. Bathymetric survey data for the site was obtained by USMI in 2016. The following were identified based on the survey data and report:

- Slopes adjacent to the jetty (between the jetty and Powerhouse intake) generally exceeded 2:1, with slopes up to 1:1 identified. A vertical section adjacent to the Powerhouse intake was identified (appears to be the concrete walls).
- Riprap material was identified as migrating towards the northwest corner of the apron in front of the Powerhouse intake from the jetty.

1.3.4 Upstream Recreational Area

The BLM Upper Toston Recreation Area is located immediately upstream of the Broadwater Project. It has three campsites, parking, a latrine, and a boat launch with a floating dock. Portions of the riverbank between the recreation areas and the Toston Dam and Broadwater-Missouri Canal Headworks have been slowly eroding. It is suspected that a combination of boat wakes and the channeled flow to the Powerhouse and headworks are facilitating the erosion.

Figure 1-3 – Powerhouse Intake As-Built Drawings



1.3.5 Geotechnical Investigations

HKM Associated performed a geotechnical investigation in 1987 as part of the Broadwater Project design/construction. The investigation included construction and logging of seven drill holes and three test pits within the project area. In general, based on this investigation, the dam footing is set within a limestone layer which is overlain by layers of: discontinuous siltstone shale; limestone; poorly graded gravel; silty sand; and fill. Bedrock is located 13 to 35 feet below the ground surface. Drill hole locations are shown in Figure 1-4, a typical soil profile in presented in Figure 1-5, and a typical boring log is shown in Figure 1-6.

Figure 1-4. Drill Hole and Soil Profile Locations.

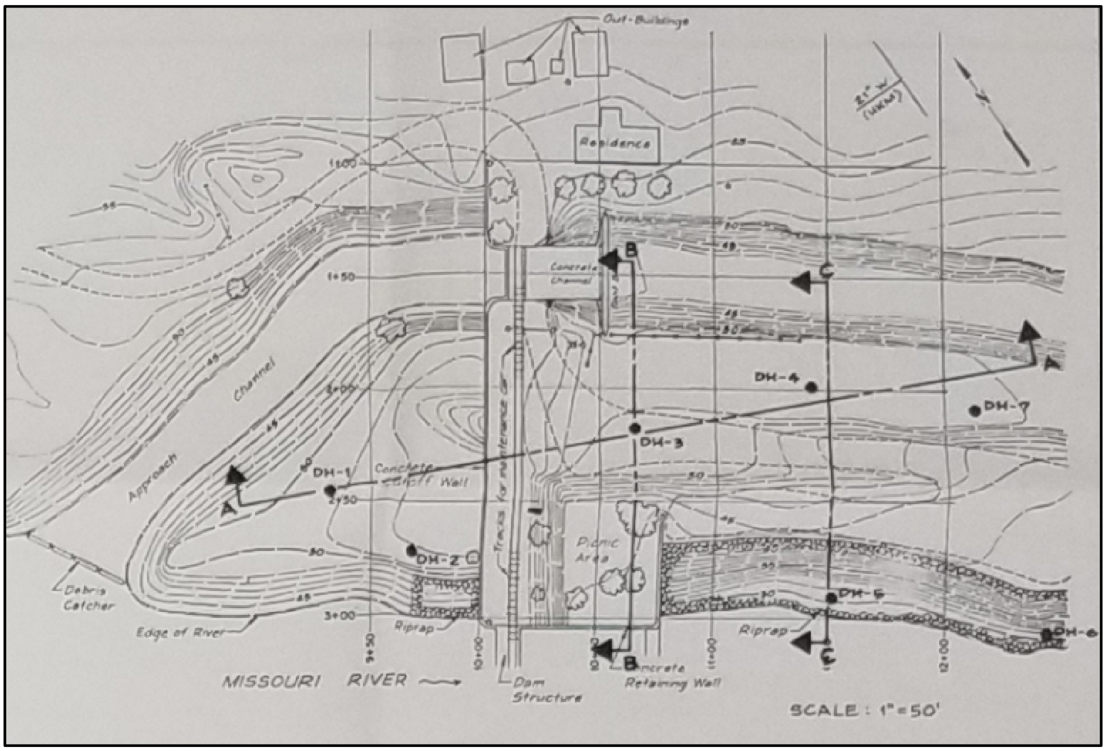


Figure 1-5. Typical Soil Profile.

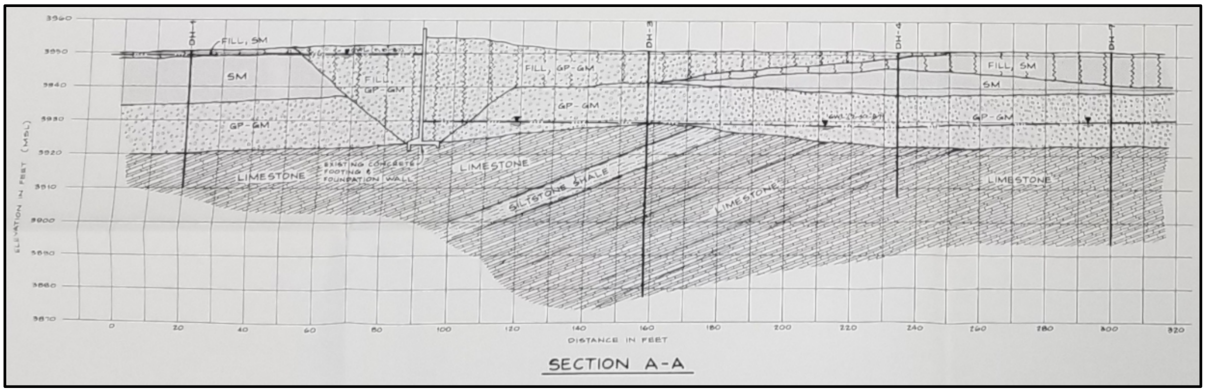
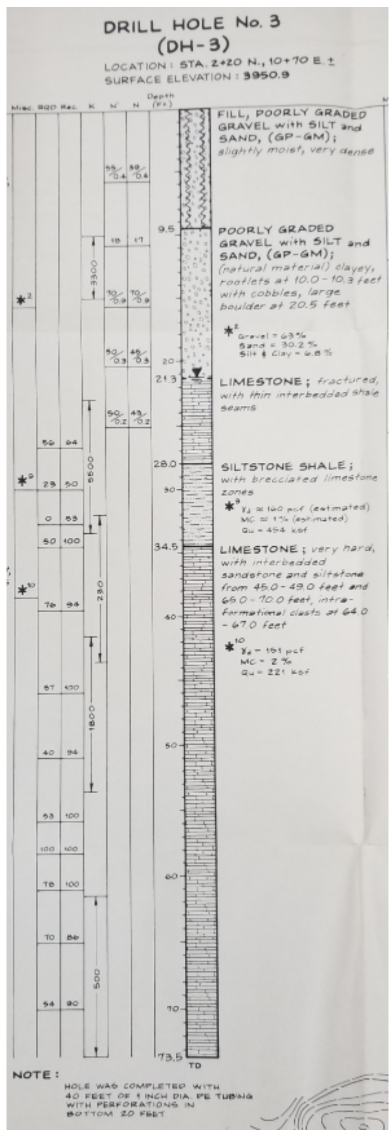


Figure 1-6. Typical Boring Log.



1.3.6 Survey Information

Existing Survey

SWPB contracted with Utility Mapping Services Incorporated (UMS) to perform hydrographic survey services immediately upstream (2017) and downstream (2016) of Toston dam. The work included high resolution, high frequency multibeam sonar bathymetric survey mapping and characterizing the subsurface to identify jetty riprap degradation. The intent was to identify locations requiring remedial work and provide high resolution mapping for monitoring subsequent conditions and ensuing maintenance and design efforts.

SWPB contracted with Northland Engineering & Survey to perform a Dam Centerline Survey. A portion of that project collected and presented control point survey data in three datum: Local Coordinate System; State Plane (2500MT), North American Vertical Datum of1988 (NAVD88) ortho height international feet; and World Geodetic System (WGS84).

New Survey

HDR staff collected both upland and supplemental bathymetric survey data on April 6-7, 2020. A Trimble R10-2 survey-grade RTK GNSS receiver system was used to collect upland data and a Sonarmite Echo sounder system was attached to a kayak to collect the supplemental bathymetric data. Data was also collected for four existing DNRC control points to tie the new data to the Local Coordinate System as well as State Plane 1983 (2500MT), Geoid 12B.

All RTK Infill data was uploaded to the National Oceanic and Atmospheric Administration's (NOAA) Online Positioning User Service (OPUS) to increase survey data precision using NOAA's Continuously Operation Reference Stations (CORS).

The new survey data were combined with the existing site survey data to produce a single topographic surface for use in preliminary project design and hydraulic modeling. Survey extents are shown in Figure 1-7.

Figure 1-7. Survey Extents.

1.4 Project Goals

Conversations with DNRC have provided the following goals for this project:

- Reconstruct or remove and stabilize the existing jetty to reduce/stop shedding of riprap into Powerhouse intake
- Protect the irrigation headworks from floating debris
- Reduce sediment (primarily sand sized) deposition and inflow at the irrigation headworks
- Assess replacement options for existing canal gates
- Stabilize riverbank at BLM recreation area.

2 Hydraulic Modeling

2.1 Overview

To analyze the range of hydraulic conditions present within the study area, a 2D hydraulic model was employed. The hydraulic analysis was performed utilizing the US Army Corps of Engineers Hydraulic Engineering Center's River Analysis System, Version 5.0.7 (RAS) hydraulic modeling software (Reference 14). This software is applicable for flows in surface-water bodies where vertical velocities and accelerations are small or relatively negligible in comparison to those in horizontal directions. RAS simulates wetting and drying of elements, providing applicability for flood inundation modeling. It can simulate sub-critical flow, super-critical flow, and the transition between the two regimes. A more complete description of model equations and assumptions are provided in the 2D Modeling User's Manual (Reference 15). Due to the flow directions and contractions, the Full Momentum Equations were employed with a maximum Courant Conditions less than one to provide the most accurate solution. Model output includes water surface elevation, depth, and velocity magnitude. Details of the techniques used to complete this analysis are presented below.

2.2 Digital Terrain Model

The digital terrain model (DTM) used to represent the bathymetry in the model domain was produced using the two different data sources noted above in Section 1.3.6. The overland areas in the domain, jetty, and bathymetric cross section of the reservoir are represented using topographic ground survey data gathered by HDR. Bathymetric data in the immediate vicinity of the dam were gathered from the survey performed by UMS and supplemented by HDR collected data. The bathymetric surface and overbank topographic data from LiDAR were merged to create a seamless DTM. The DTM created from these sources references the NAVD88.

2.3 Surface Roughness

Surface roughness in the model uses Manning's Roughness Coefficients and was assigned to corresponding land surface characteristics approximated from aerial photographs and confirmed during a site visit performed on April 6, 2020. In the modeling process, surface roughness was adjusted within standard tolerance limits (Chow 1959; USGS 1967) to stabilize the 2D model. The Manning's values for the downstream slopes of the spillway were estimated using values within standard tolerances to improve the model's stability without compromising its accuracy.

2.4 Hydraulic Structures

The geometries of the structures present within the analyzed flow paths of the RAS model were generated through the combination of field survey data and historic plan sets. The analyzed reach includes the Broadwater Dam consisting of the hydropower intake and the overtopping spillway as well as the irrigation intake for the Broadwater-Missouri Canal. Based on discussions with DNRC, it was noted that 400 cfs would enter the irrigation intake while the hydropower intake would consume 7,000 cfs. The remainder would go through the dam's spillway.

3 Alternatives Analysis

3.1 Overview

The DNRC identified the jetty, slide gate, and bank stabilization as project components to be assessed through an alternatives analysis to evaluate potential alternatives for mitigating associated deficiencies for each as follows:

- Jetty: The existing jetty is exhibiting signs of instability and settlement and is shedding jetty material towards the Powerhouse intake.
- Slide Gates: The existing gates are reaching the end of their design life and leak when fully closed which impacts operations.
- Bank Stabilization: Instability and erosion of the bank for the upstream recreational area was identified.

3.2 Opinion of Probable Construction Costs

Opinion of probable construction costs were prepared for alternatives based on estimated quantities for major items of work, and included a mobilization rate of 15%, a contingency of 30%, and engineering cost of 10% for all alternatives. Opinion of probable construction costs for each alternative are provided in their representative section.

3.2.1 Dewatering

For all alternatives, it was assumed that the upstream reservoir pool level would be maintained throughout construction (would not be lowered). Opinion of probable construction costs were prepared to reflect this assumption and included added costs and measures to facilitate construction as required for the specific alternative [e.g., dewatering (which may include cofferdam construction and pumping), divers, etc.]. Lowering of the reservoir may significantly reduce construction costs, but may have additional costs, which could include lost power generation revenue, possible damage to upstream structures, lost revenue associated with the recreational area, and irrigation damages. Following alternative selection, these factors should be closely reviewed and considered to determine the most economically viable method for construction.

3.3 Conceptual Level Life Cycle Analysis

A life cycle cost analysis was performed for alternatives for a 50-year period. All values were converted to equivalent present values using an assumed real discount rate of 5.0%, which includes both interest and inflation, to determine the 50-year present worth. For life cycle cost analysis, costs were broken into the following:

- Operation and Maintenance: Annual operation and maintenance costs.
- Rehabilitation/Overhaul: Rehabilitation/overhaul activities which are required on a reoccurring basis.
- Power: Annual power consumption costs for alternatives which require power.
- Replacement: Complete replacement of facilities or components.

3.4 Evaluation Methods and Criteria

A preliminary alternatives matrix was prepared for each of the project components, including the Jetty, Slide Gates, and Bank Stabilization. The process was used to develop a wide range of alternatives which were then scored based on a standard set of criteria (i.e. modified pairwise ranking). Strengths and risks for each alternative were considered as well as how each addressed project goals and objectives. The goal was to rank the alternatives through a numerical process such that the range of alternatives could be culled to a reasonable number and to document that the discarded alternatives had been considered. The preliminary alternative matrices for the Jetty, Slide Gates and Bank Stabilization are included in Appendix A, Appendix B, and Appendix C. DNRC comments were then used to finalize alternatives for further analysis. DNRC comments are included in Appendix D.

Alternatives retained/developed for further consideration are presented in the following sections of this report. Alternatives development is semi-conceptual in nature and are based on similar projects and typical wall and floor thicknesses, pile sizes, common gate sizes, etc. Following alternatives development, a pairwise ranking was then completed to compare alternatives based on established criteria. Additional information on the pairwise ranking can be found in Section 3.5.9.

Hydraulic analysis for developing alternatives was limited to assessing flow direction and velocities. Available geotechnical data was utilized for developing generalized assumptions, however, additional investigations are recommended for more detailed design.

3.5 Jetty

The DNRC has identified a number of deficiencies with the existing jetty which are contributing to increased floating debris accumulation at the irrigation headworks (headworks), excess sediment (sand) being delivered into the canal and impacting operations, as well as contributing to rock material shedding towards the Powerhouse intake. Conceptual design alternatives selected for further development include:

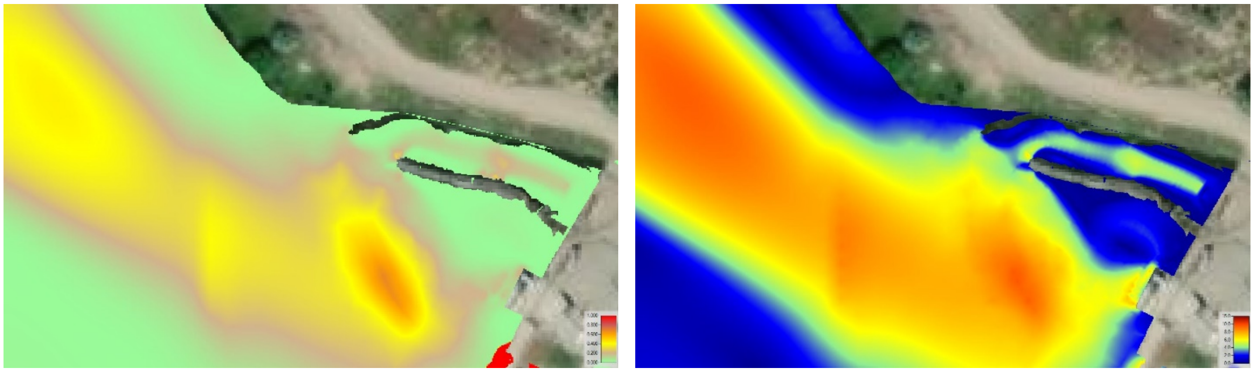
- No Action
- Floating Debris Barrier
- Floating Breakwater
- Riprap Jetty (Jetty Reconstruction)
- Flexible Intermediate Bulk Container (FIBC) Jetty (Jetty Reconstruction)
- Grout Jetty (Jetty Reconstruction)
- Sheet Pile Jetty Structure (Jetty Reconstruction)
- Trash Rake System
- Box Culvert
- Relocate Irrigation Headworks Upstream
- Relocate Irrigation Headworks Downstream

Hydraulic Model Results

Preliminary HEC-RAS hydraulic models were developed for hydraulic scenarios that represent the various conceptual designs for analyzing hydraulic characteristics including flow direction, velocities, and shear stress. The results were utilized to draw generalized conclusions for developing conceptual designs. A brief description of the preliminary hydraulic models are identified below.

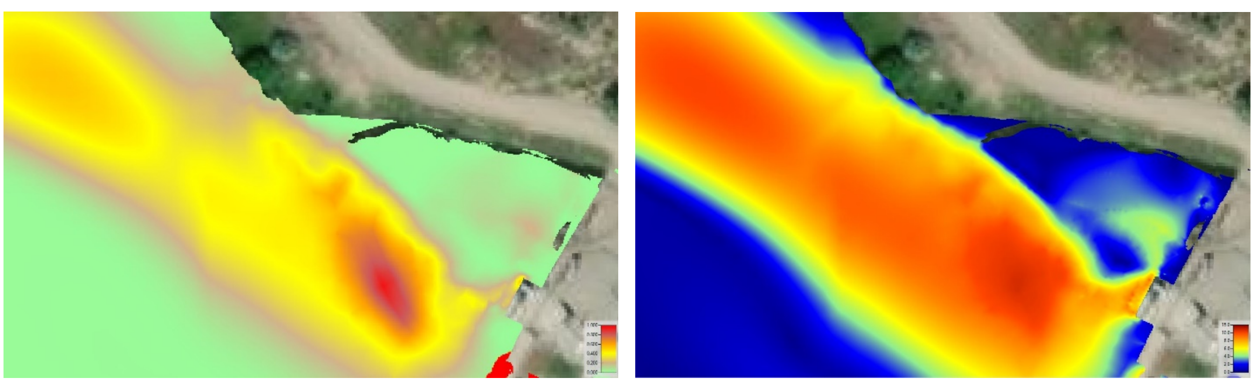
- Jetty reconstruction: This model was developed for the existing conditions and included the existing jetty. The results from the model is intended to represent alternatives in which the existing jetty is kept or is replaced with an improved jetty structure. The results were utilized for developing conceptual design alternatives which included reconstruction of the existing jetty (a layout similar to existing was assumed). Preliminary model results showed areas of increased shear stress and velocities at the entrance of the forebay channel (near the source of migrating riprap) and southwest of the existing Powerhouse intake apron. Within the forebay channel, the model showed increased velocities, indicating the potential for sediment transport towards the headworks. Figures showing the modeled shear stress and velocities are provided in Figure 3-1.

Figure 3-1. Jetty Reconstruction Shear Stresses (Left) and Velocities (Right)



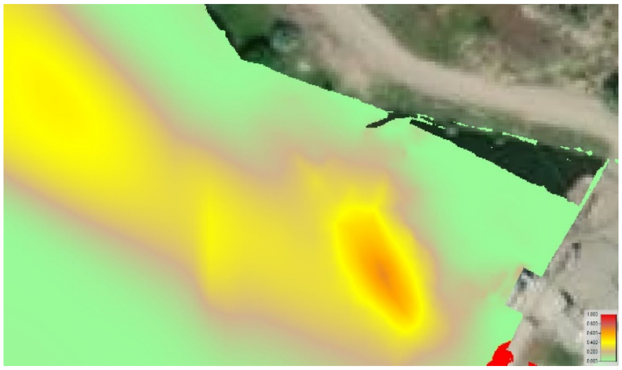
- Jetty removal: This model was developed with the assumption that the existing jetty was removed and is intended to represent alternatives in which the jetty is removed and not replaced (e.g., floating debris barrier and breakwater). The results were utilized for developing conceptual design alternatives which included permanent removal of the existing jetty. Preliminary model results showed increased shear stresses and velocities at the west end of the removed jetty (previous forebay channel entrance), and southwest of the existing Powerhouse intake apron. The model showed increased velocities immediately southwest of the headworks which decreased in adjacent to the headworks. The results indicate a decreased potential for sediment transport towards the headworks compared with the jetty reconstruction model. The model, however, does not account for a floating debris barrier, which could increase channel bottom velocities and the potential for sediment transport, particularly if submerged screens become clogged. Figures showing the modeled shear stress and velocities are provided in Figure 3-2.

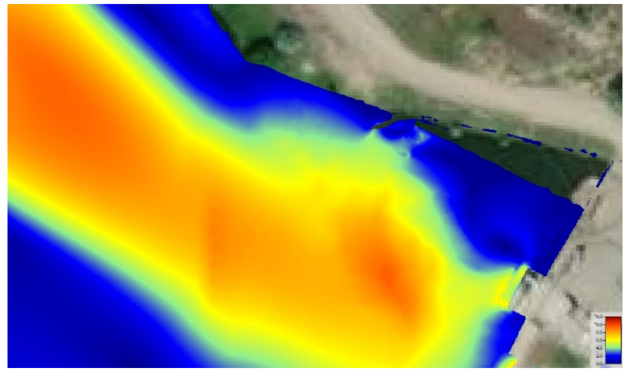
Figure 3-2. Jetty Removal Shear Stresses (Left) and Velocities (Right)



- Relocate headworks upstream: This model was developed with the assumption that the existing jetty was removed and headworks relocated upstream, with the results utilized for developing this conceptual design alternative. Preliminary model results showed a slight decrease in shear stresses at the west end of the removed jetty (previous forebay channel entrance) and entrance of the proposed headworks. Increased velocities across the front of the proposed headworks were identified in the model, as well as eddy formation adjacent to the entrance. Removal of the point bar to the west, bank realignment, and optimization of the proposed headworks alignment is recommended if this alternative is selected to avoid debris accumulation at the proposed headworks. Figures showing the modeled shear stress and velocities are provided in Figure 3-3.

Figure 3-3. Relocate Headworks Shear Stresses (Left) and Velocity (Right)





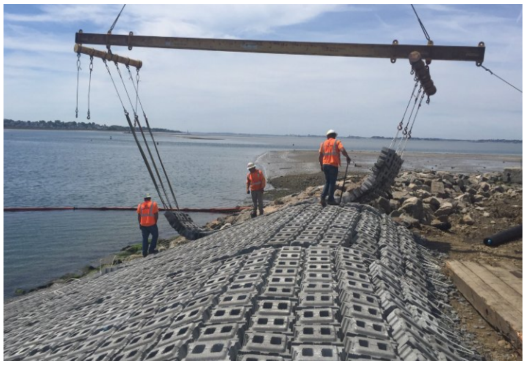
Channel Stabilization

A critical component for jetty conceptual designs is addressing channel stability adjacent to the Powerhouse intake, particularly near the source of migrating riprap. For all alternatives, it is recommended that the channel be graded from the Powerhouse intake at a slope not to exceed (no steeper than) 2:1 (horizontal:vertical). Channel stabilization, where required, should also be considered, with the following options considered for conceptual designs:

- Riprap Protection: This option would consist of armoring the channel slope with riprap, similar to the Powerhouse intake as-built drawings. This option could be constructed without divers but may requiring lowering of the reservoir to facilitate placement down to the Powerhouse intake concrete wall, if required. If not properly placed, riprap could shed towards the Powerhouse intake.
- Launching Riprap Toe: This option would consist of the construction of an oversized riprap toe near the top of the channel slope. The slope above the toe would be armored with rock mulch protection. As erosion undercuts the riprap toe, the riprap material would be re-deposited down the slope, thereby providing protection and stabilizing the slope. This option could be constructed without divers and without lowering of the reservoir, however, riprap could shed towards the Powerhouse intake.
- Concrete Armor Units (CAU): This option would consist of the installation of a row of CAUs along the channel slope. For conceptual design, A-Jacks were considered which would be cabled together in interlocking 6x7 foot modules. The A-Jacks would protect from scour and undermining to stabilize the slope, however, they would not armor the entire channel slope. This option could be constructed without lowering of the reservoir; however, divers would be required. A picture of an A-Jack system is shown in Figure 3-4 below.
- Articulating Concrete Block (ACB) Revetment: This option would consist of the installation of ACB mattresses to armor the face of the slope. The mattresses would consist of interlocking concrete blocks cabled together to form mattresses.

The ACB revetment would be placed along the channel slope to provide coverage. This option could be constructed without lowering of the reservoir, however, divers would be required. A picture of an ACB mattress being placed as shoreline protection is shown in Figure 3-4 below.

Figure 3-4. ACB Revetment (Left) and A-Jacks (Right)



For conceptual design development, the following channel stabilization measures were conservatively included in the alternatives:

- Jetty reconstruction: For alternatives including reconstruction of the existing jetty, channel stabilization measures were included for alternatives warranting additional protection from potential erosion and undermining of the jetty (grout and FIBC jetties) in the form of a 30x60 foot ACB revetment.
- Jetty removal: A 50x60 foot ACB revetment was included for channel stabilization for alternatives including permanent removal of the jetty.
- Relocate headworks upstream: Channel stabilization measures included for this alternative consisted of a riprap apron extending 30 feet from the headworks.

The need for channel stabilization, and if required, the extent, method, and detailed design and layout for channel stabilization will be determined following selection of the preferred alternative. Based on the preliminary hydraulic model results, required channel stabilization measures may not be as extensive as identified above (or even required), but were conservatively included in conceptual designs. Additional geotechnical investigations are recommended to evaluate the channel bed material and stability, as well as the extent and condition of the existing riprap, slope stability, and scour potential.

3.5.1 No Action

Alternative Overview and Discussion

The no action alternative would be comprised of continuing to operate the headworks and Powerhouse intake in its current condition with no additional improvements or modifications to the system.

Advantages

- Initial cost
- No new permitting required

- No additional impacts to existing facilities

Disadvantages

- Ongoing operation and maintenance requirements
- Would not address issues with floating debris and operation of the headworks
- Potential risk of damage to the Powerhouse intake due to the shedding of riprap
- Continued instability and settling of the jetty which would result in continued required maintenance

Opinion of Probable Construction Cost and Life Cycle Analysis

The no action alternative would have no initial costs associated with the alternative, however, there would be costs associated with continued maintenance and replacement of shed rock. A 50-year life cycle cost analysis for the alternative is provided in

Table 3-1. Replacement of the existing slide gates was assumed in 20 years, and replacement of the existing floating debris barrier on a 10-year cycle was assumed. Rehabilitation of the existing jetty, comprised of the additional riprap placement, on a 10-year cycle was assumed. Not reflected in the cost is possible significant damage to the Powerhouse intake which could result from the continued shedding of riprap from the jetty.

Table 3-1. No Action 50-Year Life Cycle Analysis

Description of Work	Present Value (2020 Dollars)
Operation and Maintenance	$146,047
Rehabilitation/Overhaul	$36,286
Power	$0
Replacement	$60,938
Present Value Subtotal	$228,506
50-Year Present Worth	**$228,506**

3.5.2 Floating Debris Barrier

Alternative Overview and Discussion

Floating barriers are a widely used and effective method for controlling floating debris. The floating debris barrier alternative would consist of a floating debris barrier with submerged screens extending below the barrier. To address the aforementioned “load rejection” events, it is proposed that the floating debris barrier be comprised of two different barrier systems, one with a deep screen system for use adjacent to the headworks, and the second with a shallow screen system for use at the west end of the barrier, furthest from the headworks. The deep screen system would be comprised of horizontal structural tubing which would extend 8 feet below the barrier. The shallow screen system would be comprised of a standard screen system which would extend 2-5 feet below the barrier. The deep screen system could be utilized for the entire barrier length but would be considerably more expensive. Different floating debris barrier systems and configurations could be considered and incorporate features such as walkways. The existing headworks would remain in-place. A floating debris barrier with 2-foot submerged screens is shown in Figure 3-5, and a floating debris barrier with 8-foot submerged screens is shown in Figure 3-6.

For this alternative, it was assumed that the floating debris barrier would protect the irrigation headworks. For cost analysis, 200 total feet of floating debris barrier, with 100 feet of both the deep and shallow screen systems was assumed. A conceptual layout of the alternative is presented in Appendix E. Detailed design, including for anticipated debris and ice loading, would occur if this alternative is selected.

In the event that the screen becomes clogged, channel bottom velocities under the floating debris barrier, and associated sediment transport and deposition, may increase. For this alternative, a new cast-in-place concrete sill/weir would be constructed in front of the headworks to mitigate sedimentation at the headworks and facilitate the removal of deposited sediment. Detailed design would occur if this alternative is selected. For channel stabilization, the existing jetty will be removed and a 50x60 foot underwater ACB revetment system would be constructed. Additional details of the ACB revetment system are provided in Section 3.5.

Figure 3-5. Elastec Brute Boom Floating Debris Barrier

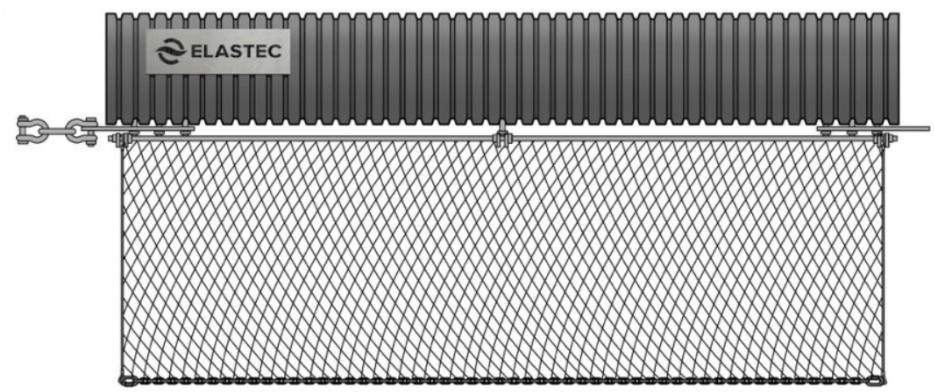
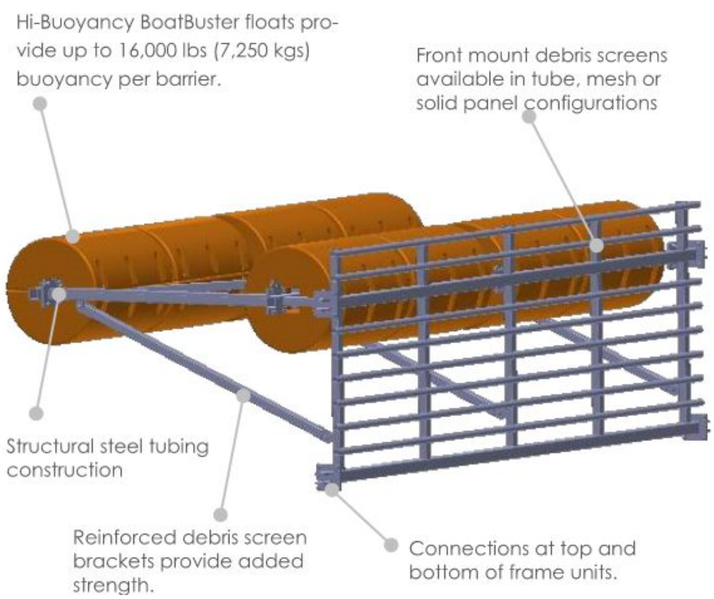


Figure 3-6. Worthington BB20 Extreme Duty Floating Debris Barrier



Advantages

- Maintains the existing headworks
- Effective at controlling floating debris and suspended debris near the surface
- Minimal visual impacts
- Minimal permitting for the floating debris barrier
- Simple to install with no specialized equipment required
- The barrier could be left in-place year round
- The barrier could be installed to protect the Powerhouse intake
- Would not require reconstruction of the jetty after jetty removal

Disadvantages

- Some floating debris may still pass the barrier, and debris collected on the barrier and screens may need to removed
- Cleaning of the screens could require removing of the barrier
- Limited service life of 10-15 years (due primarily to the hardware)
- The barrier alone does not address channel stabilization and may need to be combined with ACBs
- Velocities may increase at the channel bottom if the screen becomes clogged, which may result in increased sediment transport and deposition
- Construction of a new concrete sill would require dewatering

Opinion of Probable Construction Cost and Life Cycle Analysis

An opinion of probable construction cost was prepared for the alternative assuming a total floating debris length of 200 feet and is provided in Table 3-2. If the reservoir level were lowered, the construction cost for dewatering, jetty removal, and channel stabilization would decrease.

Table 3-2. Floating Debris Barrier Opinion of Probable Construction Cost

Description of Work	Amount
Concrete Sill	$74,800
Dewatering	$250,000
Jetty Removal	$67,500
Channel Stabilization	$120,000
Floating Debris Barrier	$145,000
Mobilization (15%)	$98,595
Contingency (30%)	$226,769
Engineering (10%)	$98,266
Total	**$1,080,930**

A 50-year life cycle cost analysis for the alternative is provided in

Table 3-3. Replacement of the floating debris barrier on a 10-year cycle was assumed.

Table 3-3. Floating Debris Barrier 50-Year Life Cycle Analysis

Description of Work	Present Value (2020 Dollars)
Operation and Maintenance	$45,640
Rehabilitation/Overhaul	$12,401
Power	$0
Replacement	$119,435
Present Value Subtotal	$177,476
50-Year Present Worth[1]	**$1,258,406**

[1]Includes initial construction cost

Permitting Requirements

- Permitting would be required for jetty removal, channel stabilization, and dewatering for concrete sill construction, and would be more extensive for the jetty removal and channel stabilization due to the dredging and placement of material in the reservoir. Permitting requirements for the floating debris barrier would be minimal. See Section 4 for additional information on permitting.

Additional Discussion

- Lowering of the reservoir would decrease overall cost and simplify construction.
- If the floating debris barrier were extended to protect the Powerhouse intake, additional mid-barrier supports may be required. In addition, the alignment would also be less conducive for the natural shearing of floating debris (i.e., additional maintenance effort may be required to remove floating debris from the barrier).
- See Section 3.5 for additional details on the ACB revetment system.

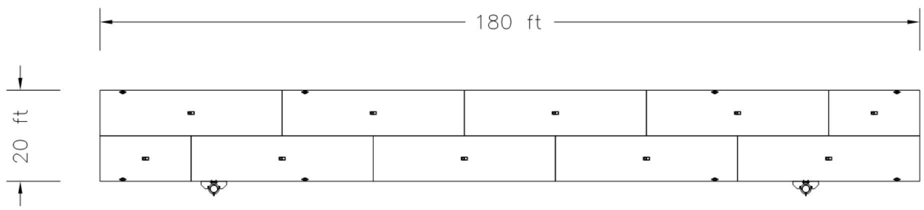
3.5.3 Floating Breakwater

Alternative Overview and Discussion

The floating breakwater alternative would be identical to the floating debris barrier, except that it would consist of a floating barge system in place of the floating debris barrier. The floating barge would be placed on the same alignment as the floating debris barrier but would consist of floats capable of supporting equipment. The existing rock jetty would be removed. A barge system with two staggered rows of floats for lateral support for a total width of 20 feet and capable of supporting equipment was assumed for this alternative. An anchoring system for mid-span lateral support of the barge, such as spuds, would be required. Depending on the jetty design/material, the draft would provide some control of suspended floating debris. A Flexifloat barge system with 14 inches of draft and a typical barge layout with spuds are shown in Figure 3-7 and Figure 3-8, respectively. Similar to the floating debris barrier, as a result of the floating barge draft, channel bottom velocities under the floating barge may increase. A new cast-in-place concrete sill/weir is assumed for this alternative.

Figure 3-7. Example of Flexifloats Used to Create a Floating Barge.

Figure 3-8. Flexifloat Barge Floating Barge Layout



Advantages

- Maintains the existing headworks
- Effective at controlling floating debris and suspended debris near the surface
- Minimal permitting for the floating breakwater
- The jetty could be left in year-round
- The jetty would facilitate equipment access
- A service life of 40+ years if properly maintained
- Would not require reconstruction of the jetty after jetty removal

Disadvantages

- Some floating debris may still pass the barrier at the ends
- Some suspended floating debris may pass underneath the barrier
- A crane may be required for installation of the floats
- The breakwater alone does not address channel stabilization and may need to be combined with ACBs
- Velocities may increase at the channel bottom due to the jetty draft, which may result in increased sediment transport and deposition
- Construction of a new concrete sill would require dewatering

Opinion of Probable Construction Cost and Life Cycle Analysis

An opinion of probable construction cost was prepared for the alternative assuming a total floating debris length of 200 feet and is provided in

Table 3-4. If the reservoir level were lowered, the construction cost for dewatering, jetty removal, and channel stabilization would decrease.

Table 3-4. Floating Breakwater Opinion of Probable Construction Cost

Description of Work	Amount
Concrete Sill	$74,800
Dewatering	$250,000
Jetty Removal	$67,500
Channel Stabilization	$120,000
Floating Barge	$522,000
Mobilization (15%)	$155,145
Contingency (30%)	$356,834
Engineering (10%)	$154,628
Total	**$1,700,906**

A 50-year life cycle cost analysis for the alternative is provided in Table 3-5. Replacement of the floating barge on a 40-year cycle, and pressure testing and repainting of the floats on a 4-year cycle was assumed.

Table 3-5. Floating Breakwater 50-Year Life Cycle Analysis

Description of Work	Present Value (2020 Dollars)
Operation and Maintenance	$18,256
Rehabilitation/Overhaul	$62,912
Power	$0
Replacement	$74,148
Present Value Subtotal	$155,615
50-Year Present Worth[1]	**$1,856,222**

[1]Includes initial construction cost

Permitting Requirements

- Permitting requirements are anticipated to be the same as for the floating debris barrier alternative.

Additional Discussion

- Alternative floating breakwater designs and layouts could be considered, except that there would not be an option to cost-effectively extend the floating breakwater to protect the Powerhouse intake. To maintain the integrity of the barge system identified, pressure testing and repainting of the floats on a 3- to 5-year cycle is recommended.

3.5.4 Jetty Reconstruction

Reconstruction of the existing jetty with a new jetty would be a permanent long-term solution. Different materials and construction techniques could be utilized for reconstruction of the existing jetty. Four alternatives selected as the most feasible for reconstruction of the jetty are presented below.

Riprap Jetty

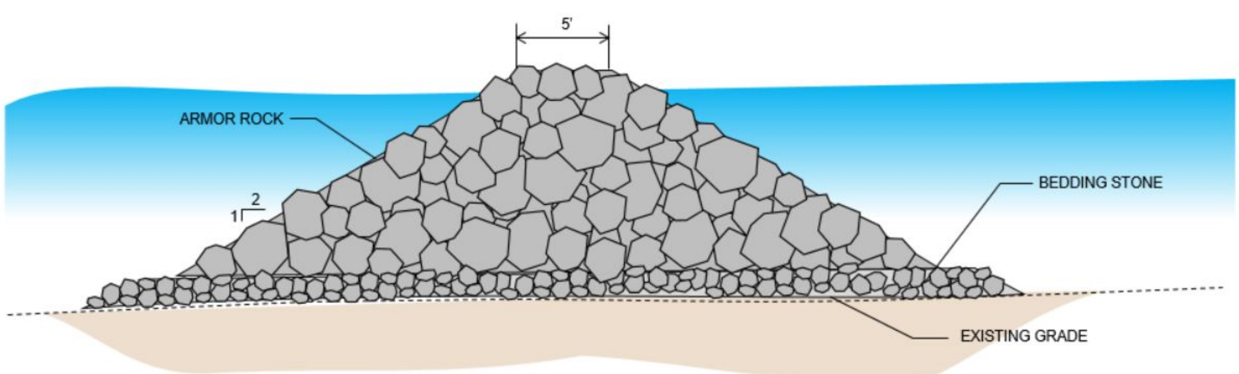
Alternative Overview and Discussion

The riprap jetty alternative would consist of the reconstruction of the existing jetty with riprap. The existing jetty would be removed to the extent required for foundation stability, and a new riprap jetty would be constructed utilizing, conceptually, 24-inch riprap in approximately the same location. The new riprap jetty would have sides sloped at 2:1 and a 5-foot crest width. These dimensions would be further evaluated during final design. A typical section for the riprap jetty is identified in Figure 3-9.

Due to the flattening of the side slopes, the footprint of the jetty would expand to the north and the forebay channel would be realigned as shown in the conceptual layout of the alternative presented in Appendix F. The existing irrigation headworks would remain in-place, however, construction of a transition section and/or wing walls in conjunction with warping/steepening of the riprap jetty inslopes would be required to maintain the headworks entrance and avoid the relocation of the headworks. Construction of a cast-in-place concrete transition was assumed for this alternative. Detailed design would occur if this alternative is selected. The forebay channel banks on the opposite side of the forebay channel (north) would be realigned and would have 2:1 side slope with riprap protection near the entrance and upstream of the headworks.

Due to the forebay channel bank realignment, the adjacent roadway to the north would be impacted and would need to be relocated and shifted approximately 15-20 feet to the north, resulting in the required reconstruction of 250 feet of roadway. Blasting may be required to facilitate relocation of the roadway and was assumed for the opinion of probable construction cost. It is anticipated that impacts to the 3-phase power line adjacent to the roadway could be avoided, however, protection with guardrail is recommended. Guardrail would also be placed along the 2:1 slope adjacent to the realigned forebay channel. A floating debris barrier would be installed at the entrance to the forebay channel.

Figure 3-9. Riprap Jetty Typical Section.



ADVANTAGES

- Maintains the existing headworks
- Durable and proven permanent solution when properly constructed
- When properly installed, riprap is “self-healing”
- Effective at controlling floating and suspended debris
- Would not contribute to increased sedimentation at the headworks
- Minimal O&M required and no mechanical component to maintain other than floating debris barrier
- Riprap could be locally sourced and existing jetty riprap material could be reused
- Construction could occur without lowering of the reservoir or dewatering
- The new riprap jetty would address channel stabilization

DISADVANTAGES

- A barge would be required to facilitate construction
- Significant underwater work in the reservoir and associated permitting required
- Will require moving of the roadway and realigning of the forebay channel
- Road access to the recreational area may be impacted during construction
- Construction of the new concrete transition would require dewatering
- Floating debris may enter the canal forebay with debris barrier installation

Opinion of Probable Construction Cost and Life Cycle Analysis

An opinion of probable construction cost was prepared for the alternative and is provided in Table 3-6. If the reservoir level were lowered during construction, the cost for dewatering, jetty removal, riprap jetty construction would decrease.

Table 3-6. Riprap Jetty Opinion of Probable Construction Cost

Description of Work	Amount
Concrete Transition	$104,300
Dewatering	$250,000
Jetty Removal	$67,500
Riprap Jetty	$400,300
Move Roadway	$153,300
Mobilization (15%)	$146,310
Contingency (30%)	$336,513
Engineering (10%)	$145,822
Total	**$1,604,045**

A 50-year life cycle cost analysis for the alternative is provided in Table 3-7. Replacement of the floating debris barrier on a 10-year cycle was assumed.

Table 3-7. Riprap Jetty 50-Year Life Cycle Analysis

Description of Work	Present Value (2020 Dollars)
Operation and Maintenance	$9,128
Rehabilitation/Overhaul	$2,903
Power	$0
Replacement	$14,514
Present Value Subtotal	$26,545
50-Year Present Worth[1]	**$1,630,590**

[1]Includes initial construction cost

Permitting Requirements

- Permitting requirements for this alternative would be very extensive due to the work occurring within the banks of the reservoir, including bank realignment and the dredging and placement of material into the reservoir. See Section 4 for additional information on permitting.

Additional Discussion

- Lowering of the reservoir would decrease overall cost and simplify construction.
- Alternative methods for retaining the jetty inslope at the headworks entrance which could be implemented without dewatering, such as the use of precast concrete shapes, could decrease overall cost

Flexible Intermediate Bulk Container (FIBC) Jetty

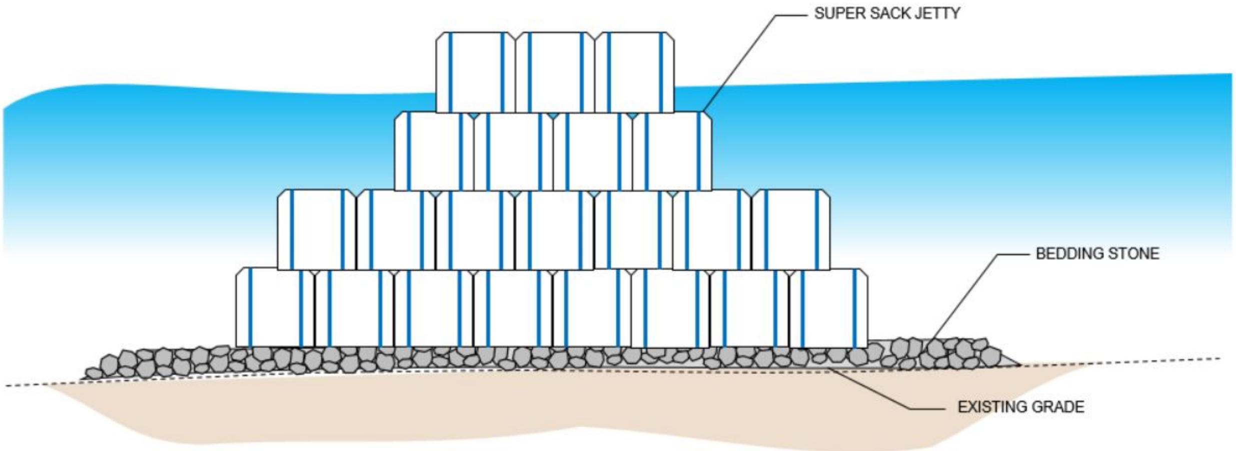
Alternative Overview and Discussion

The FIBC jetty alternative would consist of the reconstruction of the existing jetty with flexible intermediate bulk containers filled with concrete. The existing jetty would be removed to the extent required for foundation stability. Bedding stone would be placed and FIBCs filled with concrete would be stacked to form a new jetty approximately in the same location as the existing jetty. 1 cubic yard FIBCs with a lifting capacity of 4,000 lbs for the placement of 1 cubic yard of concrete were assumed for this alternative. Without lowering of the reservoir, divers may be required to assist during FIBC placement. Due to the limited life expectancy of the FIBCs, the bags would be sacrificial and would deteriorate, leaving the concrete material behind. A FIBC sack and typical section for the jetty are shown in Figure 3-10 and Figure 3-11. Detailed FIBCs jetty design and layout, as well as an evaluation of alternative jetty alignments to maximize debris control and cost effectiveness, would occur if this alternative is selected.

Due to the ability to stack the bags at a steeper slope resulting in a smaller footprint than the riprap jetty, impacts to the headworks and forebay channel are not anticipated. A floating debris barrier would be installed at the entrance to the forebay channel. For channel stabilization and to prevent erosion and undermining of the jetty, a 30x60 foot underwater ACB revetment system would be constructed, with additional details provided in Section 3.5.

Figure 3-10. Typical FIBC.

Figure 3-11. FIBC Jetty Typical Section.



ADVANTAGES

- Maintains the existing headworks
- Effective at controlling floating and suspended debris
- Would not contribute to increased sedimentation at the headworks
- Minimal O&M and no mechanical components to maintain
- Construction could occur with lowering of the reservoir or dewatering

DISADVANTAGES

- A barge would be required to facilitate construction
- Significant construction work in the reservoir and associated permitting required
- As FIBCs deteriorate, they may create undesired visual impacts as remnant material travels downstream
- Potential water quality impacts from underwater concrete placement
- Efficient stacking of individual super sacks underwater could be challenging
- The jetty does not fully address channel stabilization

- Floating debris may enter the canal forebay with debris barrier installation

Opinion of Probable Construction Cost and Life Cycle Analysis

An opinion of probable construction cost was prepared for the alternative and is provided in Table 3-8. If the reservoir level were lowered during construction, the cost for jetty removal, super sack jetty construction, and rebuilding of the opposite bank would decrease.

Table 3-8. FIBC Jetty Opinion of Probable Construction Cost

Description of Work	Amount
Jetty Removal	$67,500
Channel Stabilization	$72,000
Super Sack Jetty	$629,500
Mobilization (15%)	$115,350
Contingency (30%)	$265,305
Engineering (10%)	$114,966
Total	**$1,264,621**

A 50-year life cycle cost analysis for the alternative is provided in Table 3-9. Replacement of the floating debris barrier on a 10-year cycle was assumed.

Table 3-9. FIBC Jetty 50-Year Life Cycle Analysis

Description of Work	Present Value (2020 Dollars)
Operation and Maintenance	$9,128
Rehabilitation/Overhaul	$1,451
Power	$0
Replacement	$21,771
Present Value Subtotal	$32,351
50-Year Present Worth[1]	**$1,296,971**

[1]Includes initial construction cost

Permitting Requirements

- Permitting requirements for this alternative would be extensive due to the work occurring within the banks of the reservoir, including the dredging and placement of material into the reservoir. Additional water quality permitting may be required for underwater concrete placement. See Section 4 for additional information on permitting.

Additional Discussion

- Lowering of the reservoir would decrease overall cost and simplify construction.
- As an option to decrease the required length of new jetty, the opposing bank west of the existing jetty could be rebuilt and extended into the reservoir using

riprap and capped with gravel and/or topsoil for utilization for recreational purposes, such as a viewing platform.

Grout Jetty

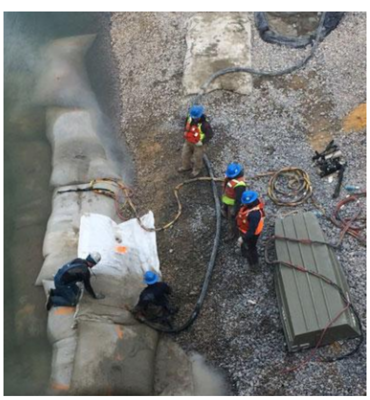
Alternative Overview and Discussion

The grout jetty alternative would consist of the reconstruction of the existing jetty with submerged grout bags filled with concrete. The existing jetty would be removed to the extent required for foundation stability. Grout bags would then be set on the bottom and a tremie would be utilized to fill the grout bags with concrete through a self-closing fill port. The new jetty would be at approximately the same locations as the existing jetty. Grout bags are available in sizes up to 220 cubic yards and could also be customized to incorporate internal structural elements for vertical sides. Standard 10x6x1.5 feet grout bags were assumed. Typical grout bags and placement, and a typical section for the jetty are shown in Figure 3-12 and Figure 3-13.

For bag placement, the bags would be filled with water and sunk to sit in their proper locations. A tremie would then be attached to the bag, and concrete would be pumped and would displace the water in the bags. Divers would be required for setting of the grout bags and concrete pumping operations. Detailed grout bag design and layout, including recommendations on the most economical grout bag size and layout, as well as an evaluation of alternative jetty alignments to maximize debris control and cost effectiveness, would occur if this alternative is selected.

Similar to the super sack jetty alternative, impacts to the headworks and forebay channel are not anticipated. A floating debris barrier would be installed at the entrance to the forebay channel. For channel stabilization and to prevent erosion and undermining of the jetty, a 30x60 foot underwater ACB revetment system would be constructed, with additional details provided in Section 3.5.

Figure 3-12. Sythetex Grout Bags and Placement



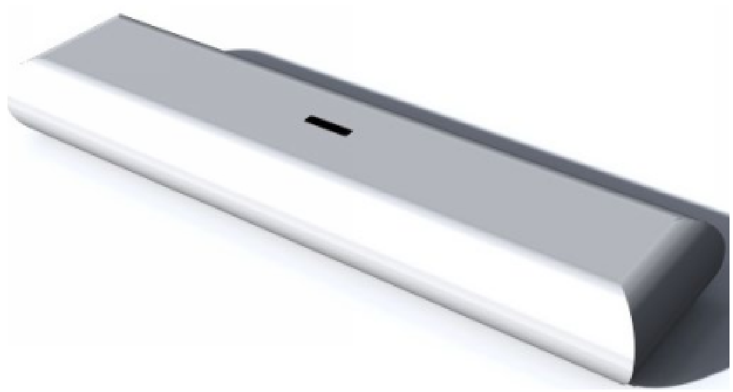
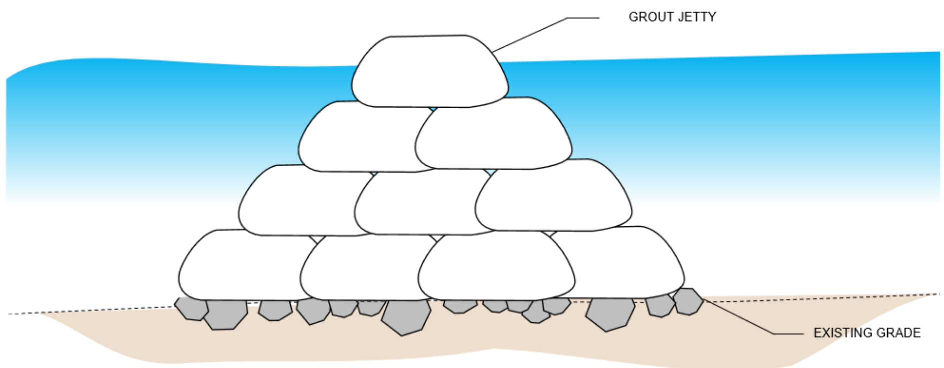


Figure 3-13. Grout Jetty Typical Section



ADVANTAGES

- Maintains the existing headworks
- Effective at controlling floating and suspended debris
- Would not contribute to increased sedimentation at the headworks
- Minimal O&M and no mechanical components to maintain
- Large grout bags allow for larger concrete pours and a more stable jetty
- Grout bags would form to the bottom and reduce voids during construction
- Higher quality cured concrete versus other methods like cure-in-place grout bags
- Construction could occur without lowering of the reservoir or dewatering

DISADVANTAGES

- Would require reconstruction of the jetty
- A barge would be required to facilitate construction
- Significant construction work in the reservoir and associated permitting required
- Grout bags will deteriorate and create visual impacts and carry downstream, however, the impacts would be considerably less than for the FIBC jetty
- Potential water quality impacts from underwater concrete placement
- Bank reconstruction would require additional permitting
- The jetty does not fully address channel stabilization
- Floating debris may enter the canal forebay with debris barrier installation

Opinion of Probable Construction Cost and Life Cycle Analysis

An opinion of probable construction cost prepared for the alternative and is provided in Table 3-10. If the reservoir level were lowered during construction, the cost for jetty removal, grout jetty construction, and rebuilding of the opposite bank would decrease. 10x6x1.5-foot grout bags were assumed for this alternative. Larger grout bags and custom structural elements could be considered but would result in increased bag costs.

Table 3-10. Grout Jetty Opinion of Probable Construction Cost

Description of Work	Amount
Jetty Removal	$67,500
Channel Stabilization	$72,000
Grout Jetty	$646,500
Mobilization (15%)	$117,900
Contingency (30%)	$271,170
Engineering (10%)	$117,507
Total	**$1,292,577**

A 50-year life cycle cost analysis for the alternative is provided in Table 3-11. Replacement of the floating debris barrier on a 10-year cycle was assumed.

Table 3-11. Grout Jetty 50-Year Life Cycle Analysis

Description of Work	Present Value (2020 Dollars)
Operation and Maintenance	$9,128
Rehabilitation/Overhaul	$1,451
Power	$0
Replacement	$21,771
Present Value Subtotal	$32,351
50-Year Present Worth[1]	**$1,324,928**

[1]Includes initial construction cost

Permitting Requirements

- Permitting requirements would be similar to the super sack jetty alternative.

Additional Discussion

- Lowering of the reservoir would decrease overall cost and simplify construction.
- As an option to decrease the required length of new jetty, the opposing bank west of the existing jetty could be rebuilt and extended into the reservoir using riprap and capped with gravel and/or topsoil for utilization for recreational purposes, such as a viewing platform.

Sheet Pile Jetty

Alternative Overview and Discussion

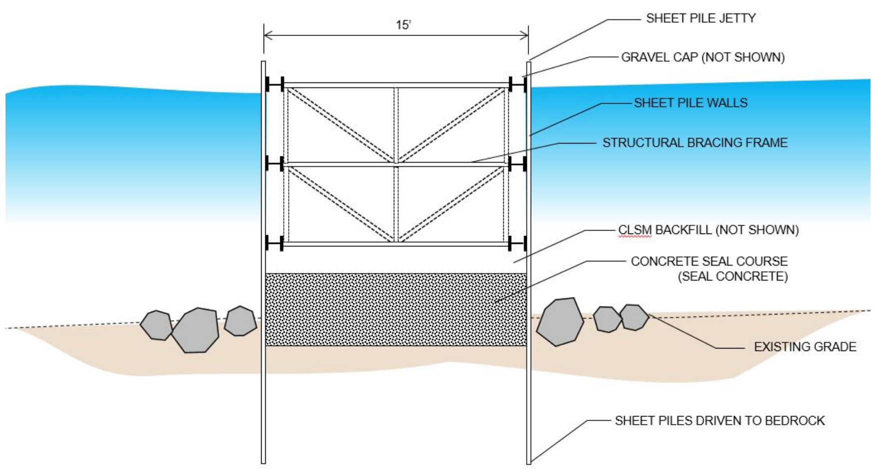
The sheet pile jetty alternative would consist of the replacement of the existing jetty with a new jetty constructed of sheet piles. Sheet piles are commonly used for cofferdam construction. The sheet pile jetty alternative would consist of the reconstruction of the existing jetty with sheet piles walls. The existing jetty would be removed to the extent required for foundation stability, and a new sheet pile jetty would be constructed in approximately the same location. The proposed sheet pile jetty would consist of two parallel sheet pile walls constructed of z-type piling with tie rods and wales for bracing.

The existing headworks would remain in-place. A conceptual layout of the alternative is presented in Appendix G.

Geotechnical data available for the project at the time of this report for the dam does not include any bore logs adjacent to the existing jetty. Available bore logs to the south indicate a limestone layer located at a depth of 20-30 feet. For this alternative, it was assumed that parallel sheet pile walls located 15 feet apart for the length of the jetty would be driven to the limestone layer. The walls would then be backfilled with underwater seal concrete to a depth of five feet and the remaining depth between the walls would be backfilled with standard concrete or controlled low strength material to just below the top of the walls. A gravel surface cap is proposed for the finished surface on top of the jetty. A typical section of a sheet pile wall section is shown in Figure 3-14. Detailed sheet pile design and layout to ensure stability of the sheet pile jetty would occur if this alternative is selected and may change significantly from the conceptual design depending on geotechnical recommendations. Bearing piles were not assumed for this alternative design but could be required for additional structural support for the sheet pile walls. In addition, different sheet pile jetty alignments would be evaluated to maximize debris control and cost effectiveness if this alternative is selected.

Impacts to the headworks and relocating of the forebay channel are not anticipated. A floating debris barrier would be installed at the entrance to the forebay channel.

Figure 3-14. Sheet Pile Wall Typical Section



ADVANTAGES

- Maintains the existing headworks
- Durability and proven permanent solution
- Effective at controlling floating and suspended debris
- Would not contribute to increased sedimentation at the headworks
- Minimal O&M and no mechanical components to maintain
- Construction could occur without lowering of the reservoir or dewatering
- The pile jetty would facilitate equipment access onto the barge
- The new sheet pile jetty would address channel stabilization

DISADVANTAGES

- Would require specialized equipment to construct
- Construction could be challenging with the 3-phase overhead powerline (e.g., lifting sheets with crane)
- Significant construction work within the reservoir and associated permitting required
- Extensive additional geotechnical investigations, including borings, would be recommended for due diligence for design. Additional required design elements could include predrilling, support piles, different wall configurations, etc.
- Challenging pile driving conditions are anticipated based on discussions with Terracon regarding the previous temporary sheet pile cofferdam construction for the Powerhouse intake.
- Concrete fill is recommended for stability
- Driving sheet adjacent to FERC licensed dam would require extra care and permitting
- Floating debris may enter the canal forebay with debris barrier installation

Opinion of Probable Construction Cost and Life Cycle Analysis

An opinion of probable construction cost was prepared for the alternative and is provided in Table 3-12. If the reservoir level were lowered during construction, the cost for jetty removal, sheet pile jetty construction, and rebuilding of the opposite bank would decrease.

Table 3-12. Sheet Pile Jetty Opinion of Probable Construction Cost

Description of Work	Amount
Jetty Removal	$67,500
Sheet Pile Jetty	$1,024,750
Mobilization (15%)	$163,838
Contingency (30%)	$376,826
Engineering (10%)	$163,291
Total	**$1,796,205**

A 50-year life cycle cost analysis for the alternative is provided in Table 3-13. Replacement of the floating debris barrier on a 10-year cycle was assumed.

Table 3-13. Sheet Pile Jetty 50-Year Life Cycle Analysis

Description of Work	Present Value (2020 Dollars)
Operation and Maintenance	$9,128
Rehabilitation/Overhaul	$1,451
Power	$0
Replacement	$14,514
Present Value Subtotal	$25,094
50-Year Present Worth[1]	**$1,821,299**

[1]Includes initial construction cost

Permitting Requirements

- Permitting requirements for this alternative would be extensive due to the work occurring within the banks of the reservoir, including the dredging and placement of material into the reservoir. Additional permitting may be required for any required pre-drilling. See Section 4 for additional information on permitting.

Additional Discussion

- Lowering of the reservoir would decrease overall cost and simplify construction.
- As an option to decrease the required length of new jetty, the opposing bank west of the existing jetty could be rebuilt and extended into the reservoir using riprap and capped with gravel and/or topsoil for utilization for recreational purposes, such as a viewing platform.
- Alternatives designs which may be considered or required based on additional geotechnical investigations and recommendations could include the following:
    - Closed cell sheet pile structure constructed of z-shape piling: This alternative would consist of sheet piles constructed as caisson cells. The cells would be connected and backfilled, similar to the conceptual design above.
    - Soldier pile wall: This alternative would consist of individual h-piles with a wall/bulkheads placed between the individual piles. Based on the available geotechnical data, predrilling and backfilling of the piles would be required, and would require the use of divers and major equipment for drilling which would result in additional environmental impacts. This would be very challenging given the site location, 3-phase overhead power line, and proximity to the face of the dam.
    - Pile dolphin: This alternative would consist of pile dolphins. Different pile configurations could be considered, including monopoles, 2-piles, 3-piles, 4-piles, etc. Predrilling of the piles would be required. Bulkhead/wall system could then be mounted off of the dolphins but would be more challenging to construct and mount.

Jetty Reconstruction Additional Discussion

Additional materials which could be considered for reconstruction of the existing jetty, but were not included in the alternatives analysis, include the following:

- Precast concrete armor units (CAUs): CAUs could be utilized in lieu of riprap and could facilitate construction at up to 1.5:1 side slope for a reduced footprint. CAUs are generally available in large sizes, would be more expensive than riprap, and would need to be procured. Smaller CAUs could be considered but may be cost-prohibitive for the jetty. CAUs would take more effort to place than riprap.
- Gabion baskets: Gabion baskets could be utilized for jetty construction and would allow for vertical walls for a reduced footprint and could also be efficiently installed without lowering of the reservoir. Welded wire mesh material, such as

used for Hilfiker Trinity Walls, are much more robust than traditional gabion basket materials and would provide added durability. Gabion baskets would be susceptible to ice damage, particularly if the reservoir level fluctuates while ice-covered. Facing material, such as shotcrete, could provide added protection from ice damage, but would require lowering of the reservoir to construct and add cost. If an alternative long-term, cost-effective, and easy to construct facing material was identified, gabion baskets could be viable.

- Reinforced concrete caissons: Reinforced concrete caissons, filled with concrete or other materials, could be utilized for jetty construction and would allow for vertical walls for a reduced footprint. Reinforced concrete caisson structures are typically used for deep water marine applications. Existing precast shapes could be considered for use, such as multi-cell box culverts. Reinforced concrete caissons would be expensive and challenging to construct and would require major equipment for placement.
- Cure-in-place grout riprap: Cure-in-place grout riprap could be utilized for jetty construction in lieu of super sacks or grout bags. This would consist of the placement of bags of unmixed concrete which would cure in place underwater. The bag material would be sacrificial. The system would consist of much smaller bags. Numerous bags would be required and would be challenging and time-consuming to place. Concrete quality would be lower than other methods, resulting in a shorter lifespan and susceptibility to freeze-thaw damage.

3.5.5 Trash Rake System

Alternative Overview and Discussion

Mechanical trash removal systems could come in a range of types and configurations, but generally would consist of a system where debris is collected on racks or screens and mechanically removed. The trash rake system alternative would consist of the installation of a new trash rake system on the canal intake. For this alternative the existing jetty would be removed. A new cast-in-place concrete sill/weir with sloped walls would be constructed in front of the headworks for mounting the new trash rack, as well as to mitigate sedimentation at the headworks and facilitate the removal of deposited sediment. Detailed sill/weir design would occur if this alternative is selected based on trash rake system requirements.

The existing trash racks would be removed, and a new trash rack system would be installed at the headworks. The trash rack could be installed from vertical to a 1:1 slope. A vertical trash rack was assumed for this alternative. A single trash rack system is recommended for operation of the trash rake and to decrease velocity differentials across the rack, however, a system utilizing separate individual trash racks could also be provided and would require fewer modifications to the existing headworks. The trash rack bar spacing design would be based on debris removal requirements and would be determined if this alternative is selected. A floating debris barrier would be installed in front of the trash racks to prevent large debris from damaging the trash rake system. A conceptual layout of the alternative is presented in Appendix H.

The trash rake system would be comprised of an automated trash rake controlled by a programmable logic control (PLC) system which could be set to manual, automatic, or continuous operation. The trash rake would deposit debris onto the deck behind the trash rake or a conveyor system which would convey debris to a common location for collection and removal. The trash rake system could be hydraulic or electromechanical. For this conceptual design, an electromechanical system with a 700-pound lift capacity was assumed. The final trash rake system design would be based on the size, type, and quantity of debris to be removed and would occur if this alternative is selected. Two possible types of trash rake system are shown in Figure 3-15 and Figure 3-16. For channel stabilization following removal of the existing jetty, a 50x60 foot underwater ACB revetment system would be constructed, with additional details provided in Section 3.5.

Figure 3-15. Atlas Polar (Hydraulic) Trash Rake System

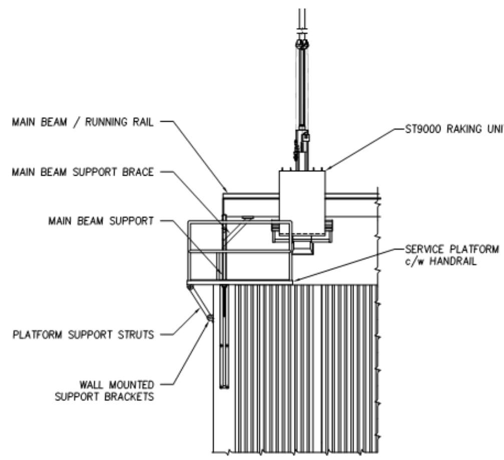
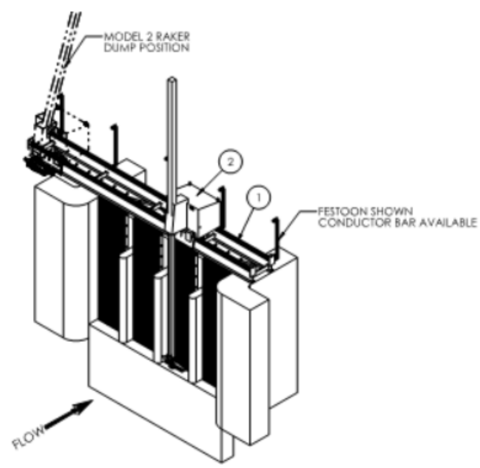


Figure 3-16. Hydro Components System (Electromechanical) Trash Rake System



Advantages

- Maintains the existing headworks
- Automated trash removal
- Electromechanical option would eliminate hydraulics
- Trash rack bar spacing can be set to target specific debris size

- Very effective at controlling debris throughout the water column
- Would not require reconstruction of the jetty
- Trash rake system would come as a complete package for easier installation
- Proven system in northern climates

Disadvantages

- Power required
- Additional O&M required for the system, including for collected debris handling
- Limited service life – a typical service life of 25-30 years is expected, however, a 40-50 year service life is possible if properly maintained
- May have issues with very long floating debris
- May contribute to increased sedimentation at the headworks
- Does not address channel stabilization
- Construction of a new concrete sill would require dewatering
- A floating debris barrier would be required in front of the trash rake system

Opinion of Probable Construction Cost and Life Cycle Analysis

An opinion of probable construction cost was prepared for the alternative and is provided in Table 3-14. If the reservoir level were lowered during construction, the cost for dewatering, jetty removal, and channel stabilization would decrease. The trash rake system assumed was an electromechanical trash rake system. The cost for a hydraulic trash rake is approximately $100,000 less than for an electromechanical trash rake.

Table 3-14. Trash Rake System Opinion of Probable Construction Cost

Description of Work	Amount
Concrete Sill	$97,300
Dewatering	$250,000
Jetty Removal	$67,500
Channel Stabilization	$120,000
Trash Rake System	$410,000
Mobilization (15%)	$141,720
Contingency (30%)	$325,956
Engineering (10%)	$141,248
Total	**$1,553,724**

A 50-year life cycle cost analysis for the alternative is provided in Table 3-15. Replacement of the trash rake system on a 30-year cycle, and of the floating debris barrier on a 10-year cycle, was assumed.

Table 3-15. Trash Rake System 50-Year Life Cycle Analysis

Description of Work	Present Value (2020 Dollars)
Operation and Maintenance	$127,791
Rehabilitation/Overhaul	$15,362
Power	$20,082
Replacement	$107,065
Present Value Subtotal	$270,301
50-Year Present Worth[1]	**$1,824,024**

[1]Includes initial construction cost

Permitting Requirements

- Permitting would be required for jetty removal, channel stabilization, and dewatering for concrete sill construction. Permitting for the jetty removal and channel stabilization would be more extensive due to the dredging and placement of material in the reservoir. Permitting requirements for trash rake system would be minor due to minimal impacts. See Section 4 for additional information on permitting.

Additional Discussion

- Lowering of the reservoir would decrease overall cost and simplify construction.
- Alternative mechanical trash removal systems were considered. The primary alternative system considered was a traveling screen. However, a trash rake system is recommended for this location for the following reasons:
  - Traveling screens would be more effective at certain types of debris, however, floating wood debris was identified as the primary debris concern, with trash rake more effective at removing woody debris. With traveling screens, longer round floating woody debris may “roll” on the traveling screen and be challenging to capture. Long and rigid floating woody debris could also dislodge the drive system for traveling screens.
  - With traveling screens, mechanical components would be located underwater and would be more difficult to maintain without lowering of the reservoir. Additional cleaning systems (e.g., water or air nozzle systems) may also be required for cleaning of the screens.

3.5.6 Box Culvert

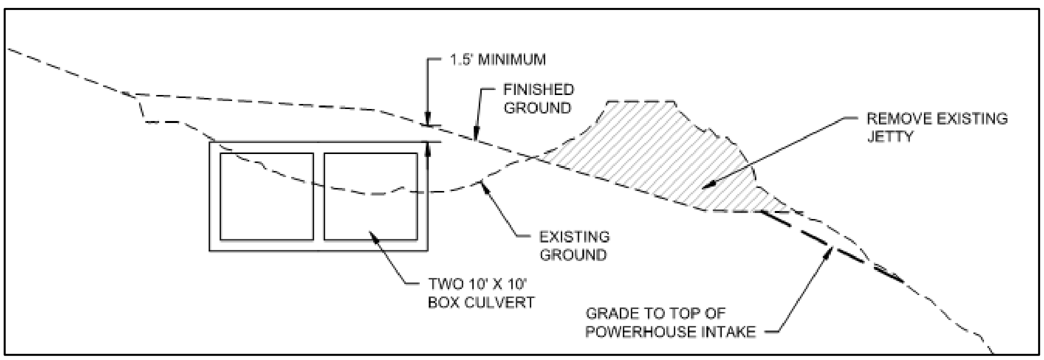
Alternative Overview and Discussion

Extension of the inlet channel upstream through the addition of box culverts would consist of a tilted screen at the approximate location of the current bridge from shore to the end of the jetty; two parallel 100’ long 10’ x 10’ culverts; and a bulkhead near the current headworks. The existing headworks would remain in place and the existing jetty would be removed. The area landward of the new culverts would be back filled and the water side would be stabilized and protected with riprap.

The new inlet alignment would provide increased protection from debris. The proposed inlet alignment is preliminary and would be optimized if this alternative is selected. The new inlet would include safety features and a new concrete sill and cutoff wall in front of the structure. The inlet would be designed with a nearly 90-degree bend downstream for tying into the box culverts with walls and vanes to reduce head losses. Total head requirements and losses would need to be evaluated to verify the capacity to deliver required irrigation diversions. This, as well as detailed design of the box culvert, and appurtenant features, would occur if this alternative is selected. A schematic cross section of the headworks for this alternative is shown in Figure 3-17, with a more detailed conceptual layout presented in Appendix J.

Extension of the box culvert and construction of the new inlet structure would require extensive rebuilding of the bank into the reservoir. The reconstructed bank would be armored with riprap. Without lowering of the reservoir, extensive dewatering would be require to facilitate construction of this alternative. For channel stabilization following removal of the existing jetty, a riprap apron would extend 30 feet from the sill of the inlet. Additional details on channel stabilization and the ACB revetment system are provided in Section 3.5.

Figure 3-17 - Box Culvert Cross Section



Advantages

- Would not require reconstruction of the jetty
- The new inlet structure could be constructed to naturally deflect debris
- The new inlet location would reduce the potential impacts caused by debris released from the powerhouse intake during sudden shutdowns
- The new location would be less susceptible to sedimentation
- The existing jetty riprap may be reused as backfill/armor protection around the river side of the new box culverts
- The existing roadway will not have to be relocated saving significant dollars in earthwork/blasting as well as providing traffic control to maintain access to public BLM recreation site during construction
- Extending the distance from the roadway to the edge of water increases roadway safety and reduces the need for additional roadway safety features
- The headworks location and construction would address channel stabilization
- Alternative has the potential to increase the size of the recreational area

Disadvantages

- Initial cost
- Significant construction work within the reservoir
- Additional geotechnical investigations would be recommended for design
- Extensive dewatering would be required

Opinion of Probable Construction Cost and Life Cycle Analysis

An opinion of probable construction cost was prepared for the alternative and is provided in Table 3-16. If the reservoir level were lowered during construction, the cost for dewatering and jetty removal would decrease.

Table 3-16 - Box Culvert Opinion of Probable Construction Cost

Description of Work	Amount
New Structures	$567,050
Box Culvert	$260,000
Dewatering	$600,000
Jetty Removal	$2,000
Mobilization	$214,358
Contingency	$493,022
Engineering	$213,643
Total	$2,350,073

A 50-year life cycle cost analysis for the alternative is provided in Table 3-19.

Table 3-17 - Box Culvert 50-Year Life Cycle Analysis

Description of Work	Present Value (2020 Dollars)
Operation and Maintenance	$27,384
Rehabilitation/Overhaul	$2,000
Power	$0
Replacement	$0
Present Value Subtotal	$30,287
50-Year Present Worth[1]	**$2,380,359**

[1]Includes initial construction cost

Permitting Requirements

- Permitting requirements for this alternative would be very extensive due to the work occurring within the banks of the reservoir, including extensive bank realignment and the dredging and placement of large volumes of fill material into the reservoir. There would be no need to change the water rights point of diversion based on the proposed layout. See Section 4 for additional information on permitting.

3.5.7 Relocate Irrigation Headworks Upstream

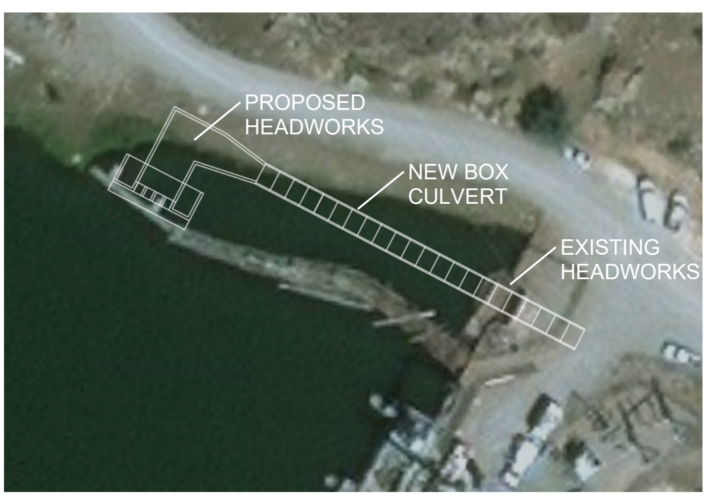
Alternative Overview and Discussion

The relocation of the headworks upstream alternative would consist of the relocation of the headworks approximately 175 feet upstream from its current location. The existing headworks would be removed back to the 10x7 foot box culvert, and 176 feet of new box culvert of the same size would extend on the same alignment to the new headworks.

A new cast-in-place concrete headworks structure would be constructed and oriented at an angle rotated approximately 90 degrees from the existing headworks to provide increased protection from debris. The proposed headworks alignment is preliminary and would be optimized if this alternative is selected. The new headworks structure would have four bays equipped with 48x87 inch manually operated stainless steel slide gates protected by trash racks. The gates could be automated, however, manually operated gates were assumed. The new headworks would include safety features and a new concrete sill and cutoff wall in front of the structure. The structure would be designed with a 90-degree bend downstream of the slide gates for tying into the box culvert with internal walls and vanes to reduce head losses. Total head requirements and losses would need to be evaluated to verify the capacity to deliver required irrigation diversions. This, as well as detailed design of the headworks, box culvert, and appurtenant features, would occur if this alternative is selected. A schematic layout of the headworks for this alternative is shown in Figure 3-18, with a more detailed conceptual layout presented in Appendix J .

Extension of the box culvert and construction of the new headworks structure would require extensive rebuilding of the bank into the reservoir. The reconstructed bank would be armored with riprap. Without lowering of the reservoir, extensive dewatering would be required to facilitate construction of this alternative. For channel stabilization following removal of the existing jetty, a riprap apron would extend 30 feet from the sill of the headworks. Additional details on channel stabilization and the ACB revetment system are provided in Section 3.5.

Figure 3-18. Relocate Irrigation Headworks Upstream Layout



Advantages

- New headworks structure with a known design life
- Would not require reconstruction of the jetty
- The new headworks structure could be constructed to naturally deflect debris
- Provides the opportunity and ability to automate water diversions
- The new location would be less susceptible to sedimentation
- The headworks location and construction would address channel stabilization
- Alternative has the potential to increase the size of the recreational area

Disadvantages

- Initial cost
- Extensive construction impacts
- The irrigation water diversion point would change
- Significant construction work within the reservoir
- Rebuilding of the headworks could require that screening for fish be considered
- Additional geotechnical investigations would be recommended for design
- Does not address channel stabilization
- Extensive dewatering would be required
- Would require removal of the existing headworks back to the existing box culvert
- Head losses due to 90-degree bend between the headworks and box culvert

Opinion of Probable Construction Cost and Life Cycle Analysis

An opinion of probable construction cost was prepared for the alternative and is provided in Table 3-18. If the reservoir level were lowered during construction, the cost for dewatering and jetty removal would decrease.

Table 3-18. Relocate Headworks Upstream Opinion of Probable Construction Cost

Description of Work	Amount
New Headworks	$1,282,525
Extend Box Culvert	$228,800
Dewatering	$600,000
Jetty Removal	$67,500
Mobilization (15%)	$326,824
Contingency (30%)	$751,695
Engineering (10%)	$325,734
Total	**$3,583,078**

A 50-year life cycle cost analysis for the alternative is provided in Table 3-19.

Table 3-19. Relocate Headworks Upstream 50-Year Life Cycle Analysis

Description of Work	Present Value (2020 Dollars)
Operation and Maintenance	$27,384
Rehabilitation/Overhaul	$2,903
Power	$0
Replacement	$0
Present Value Subtotal	$30,287
50-Year Present Worth[1]	**$3,613,364**

[1]Includes initial construction cost

Permitting Requirements

- Permitting requirements for this alternative would be very extensive due to the work occurring within the banks of the reservoir, including extensive bank realignment and the dredging and placement of large volumes of fill material into the reservoir. See Section 4 for additional information on permitting.

Additional Discussion

- Lowering of the reservoir would decrease overall cost and simplify construction.
- The recommended final angle of the headworks relative to the bank would be optimized based on hydraulic analysis to minimize debris collection.
- As an alternative to the preliminary headworks alignment shown, the tie-in to the existing box culvert could be shifted east to the location of an existing 15-degree box culvert bend located further downstream. The new alignment would extend further north and would result in the following:
  - A 150-foot increase in the length of new box culvert.
  - Increased demolition associated with additional removal of the existing box culvert and significantly more impacts to the parking area and roadway (the box culvert would be installed underneath the roadway).
  - Less impacts to the reservoir and required bank rebuilding and associated dewatering effort.
  - Additional head losses in the box culvert due to the added length and bends for changes in alignment.

3.5.8 Relocate Irrigation Headworks Downstream

Alternative Overview and Discussion

The relocation of the irrigation headworks downstream alternative would consist of constructing a new check structure which would be used to control irrigation water deliveries downstream of the existing box culvert while maintaining the existing headworks. This alternative provides no added benefit for debris control from the existing condition and would result in increased operation and maintenance. The existing headworks would remain in place and a new cast-in-place concrete check structure and wasteway would be constructed downstream of the existing box culvert outlet.

The check structure would have standard four-foot bays with stoplog guides which would accommodate 48 inch manually operated slide gates. Different gate types and configurations could be considered, and the gates could be motorized and automated. It is assumed that the existing headworks would provide the primary means for debris control. The existing trash racks would be left in-place and a floating debris barrier would be installed upstream. The existing slide gates could be left in-place or removed. If removed, dewatering of the downstream canal would be more difficult. A new wasteway structure comprised of an overflow crest and 42-inch slide gate which would outlet to a 42 inch reinforced concrete pipe would be constructed upstream of the check structure to allow for the sluicing of sediment and debris. A baffled outlet structure at the river would provide energy dissipation. The structures would be equipped with standard safety features. Detailed design of the structures and all appurtenant features would occur if this alternative is selected. A schematic layout of the new check structure and wasteway is shown in Figure 3-19 with more detailed conceptual layout presented in Appendix K.

Moving of the headworks downstream would require raising of the roadway and canal embankment upstream of the new check structure due to the increased water elevation upstream of the check structure. The box culvert design would be reviewed for the new operating conditions and lining of the canal may be required to prevent excessive seepage resulting from the raised water surface elevation. For channel stabilization following removal of the existing jetty, a 50x60 foot underwater ACB revetment system would be constructed, with additional details provided in Section 3.5.

Figure 3-19. Relocate Irrigation Headworks Downstream Layout

Advantages

- New structures with known design lives
- Would not require reconstruction of the jetty
- More accurate measurement and control of water delivered downstream
- Provides the opportunity and ability to automate water diversions
- Effective at controlling floating and suspended debris at the check structure
- Less susceptible to sedimentation with the ability to sluice sediment

- Provides a wasteway in the downstream canal

Disadvantages

- The existing headworks would still be in-place with less remaining design life than the new structures, and would be required to be operational
- May impact the new downstream water measurement structure
- Potential seepage concerns for the downstream canal and existing box culvert due to an increased operating water surface elevation
- Does not address concerns with floating debris, and separate measures for controlling debris upstream of the existing headworks would still be required
- Additional structures to operate and maintain
- Requires significant raising of the canal bank and roadway
- Dewatering of the box culvert and canal would be challenging
- Permitting for new wasteway structure
- Does not address channel stabilization

Opinion of Probable Construction Cost and Life Cycle Analysis

An opinion of probable construction cost was prepared for the alternative and is provided in Table 3-20. If the reservoir level were lowered during construction, the cost for jetty removal and channel stabilization would decrease.

Table 3-20. Relocate Headworks Downstream Opinion of Probable Construction Cost

Description of Work	Amount
New Headworks & Wasteway	$400,675
Raise Roadway Grade	$307,000
Dewatering	$100,000
Jetty Removal	$67,500
Channel Stabilization	$120,000
Mobilization (15%)	$149,276
Contingency (30%)	$343,335
Engineering (10%)	$148,779
Total	**$1,636,565**

A 50-year life cycle cost analysis for the alternative is provided in Table 3-21. Replacement of the floating debris barrier on a 10-year cycle was assumed, and replacement of the existing headworks gates in 15 years was assumed.

Table 3-21. Relocate Headworks Downstream 50-Year Life Cycle Analysis

Description of Work	Present Value (2020 Dollars)
Operation and Maintenance	$100,408
Rehabilitation/Overhaul	$7,257
Power	$0
Replacement	$62,177
Present Value Subtotal	$169,482
50-Year Present Worth[1]	**$1,806,407**

[1]Includes initial construction cost

Permitting Requirements

- Permitting requirements for this alternative would be required for the work occurring within the banks of the reservoir as well as construction of the new baffled outlet for the wasteway structure within the banks of the river. See Section 4 for additional information on permitting.

Additional Discussion

- Lowering of the reservoir would decrease overall cost and simplify construction.

3.5.9 Comparison of Alternatives

For evaluating and comparing alternatives, a pairwise ranking was utilized. The pairwise ranking considered the eight criteria listed below in Table 3-22.

Table 3-22. Pairwise Ranking Criteria

Criteria	Definition
Operation and Maintenance Requirements (O&M)	Level of effort to operate and maintain the facilities
Floating Debris Susceptibility (Floating Risk)	Potential for impacts to the functionality or integrity of the facilities due to floating debris loading/collection
Geomorphic Susceptibility (Sediment Risk)	Potential for impacts to the functionality or integrity of the facilities due to erosion, instability, and sediment transport/deposition (geomorphic processes)
Impacts to the Dam/Hydropower Intake Risk (Dam Impacts)	Potential for impacts to the hydropower intake due to channel bed instability and material shedding into the channel in front of the hydropower intake screens and structural risk to the dam
Structure Replacement Frequency (Structure Replacement)	Frequency of structure replacement or major overhauls/refurbishment (structure design life/longevity)
Design & Construction Complexity (Complexity)	Complexity of the design and amount of specialty skills and/or equipment required during construction, the extent of work within the reservoir and dewatering requirements, the extent of modifications to existing facilities
Construction & Life Cycle Analysis Cost (Cost)	50-year present worth, including initial construction cost and level of effort to operate and maintain the facilities
Permitting Level of Effort (Permitting LOE)	Level of effort and number of permits required to mitigate impact of construction on the riverine environment

A pairwise ranking was first completed to weight the ranking criteria. Next, values were assigned to each criterion on a scale of 1-5 based on the value that the alternative provides, 1 being poor/low value, and 5 being excellent/high value. Table 3-23 identifies the weighting factor applied to each criteria and final pairwise ranking results.

Table 3-23. Conceptual Design Ranking

	O&M	Floating Risk	Sediment Risk	Dam Impacts	Structure Replacement	Complexity	Cost	Permitting LOE	Weighted Average	Rank
Alternative[1]	**0.13**	**0.14**	**0.14**	**0.16**	**0.11**	**.011**	**0.17**	**0.04**	**-**	**-**
No Action	1	1	1	1	1	5	5	5	2.29	10
Floating Debris Barrier	1	3	4	4	2	4	4	4	3.26	6
Floating Breakwater	2	3	4	4	3	4	2	4	3.15	8
Riprap Jetty	4	4	4	3	5	2	3	2	3.48	1
FICB Jetty	3	4	4	4	4	2	3	3	3.44	3
Grout Jetty	3	4	4	4	4	2	3	3	3.44	3
Pile Jetty	4	4	4	4	5	1	2	2	3.36	5
Trash Rake System	2	5	3	3	3	3	2	4	3.01	9
Box Culvert	4	4	4	5	5	2	1	1	3.41	4
Relocate Irrigation Headworks Upstream	3	4	4	5	5	1	1	1	3.17	7
Relocate Irrigation Headworks Downstream	1	2	2	4	3	1	2	2	2.19	11

[1]Ranking of alternatives was based on a scale of 0-5, where 1 indicates low value (i.e., poor performance), 3 indicates neutral value, and 5 indicates high value (i.e., excellent performance).
The weighting identified in row 2 was based on the pairwise ranking.

Results from the pairwise ranking identified the riprap jetty as the highest rated alternative. The Grout Jetty and FIBC Jetty alternatives had identical ratings, followed closely by the Box Culvert and the Pile Jetty alterative. The Floating Debris Barrier and the Relocate Irrigation Headworks Upstream alternative were rated slightly lower than the above alternatives. Alternatives 7-10 (Trash Rake System, Floating Breakwater, Relocate Headworks Downstream, and No Action) had ratings much lower than the other alternatives.

3.6 Irrigation Headworks Slide Gates

Irrigation water diversions to the Broadwater Canal are controlled by four existing surface mounted slide gates at the headworks, with individual vertical trash racks located upstream of each gate. The slide gates are 48x87 inches with 16-foot-tall frames, with one gated motorized and the remaining three manually operated. Replacement of the existing slide gates could improve operations and reduce maintenance. Different gate types and configurations, as well as motorization, automation, and the incorporation of Supervisory Control and Data Acquisition (SCADA), could be considered. Undershot gates, such as slide gates currently installed, are able to pass sediment but are less capable of handling floating debris. Overshot gates, such as pivoting weir gates, are more able to pass minor floating debris but less capable of passing sediment. The following provides a discussion on alternatives reviewed for mitigating deficiencies with the existing slide gates that impact operations.

3.6.1 No Action

Alternative Overview and Discussion

The no action alternative would be comprised of continuing to operate the headworks using the existing slide gates with no additional improvements or modifications.

Advantages

- Initial cost
- No additional impacts to existing facilities

Disadvantages

- No improvements to current operations or gate leakage
- Would make automation and the incorporation of SCADA more difficult
- Gate seal replacement or gate replacement would be required in the near future

3.6.2 Replace Slide Gates

Alternative Overview and Discussion

The slide gate replacement alternative would consist of the replacement of the existing slide gates in-kind. This alternative assumed that the slide gates would be replaced with new 48x87 inch stainless steel surface mounted slide gates with 16-foot-tall frames designed for 15 feet of seating and unseating head and seals to minimize leakage. A range of options were included in the alternative, including manual operators, motorization, and automation and the incorporation of SCADA. The alternative also included costs for concrete repair-work on the existing headworks and removal of the existing gates. Minor concrete repair-work was assumed.

Final gate design would be based on the jetty alternative selected and effectiveness of the alternative at controlling floating debris and sediment transport and deposition, with different types and configurations of gates considered as applicable. The cost for overshot gates would increase over the current slide gate costs and require additional modifications to the headworks. The condition of the headworks will need to be evaluated to determine if more or less-extensive concrete repair-work would be required for new gate installation. For the headworks relocation alternatives, new slide gates for those alternatives were assumed to be the same as identified for this alternative. A picture of a typical fabricated slide gate is shown in Figure 3-20.

Figure 3-20. Fresno Fabricated Slide Gate (Manually Operated)

Advantages

- New gates with known design life
- Reduced leakage
- Ability to motorize, automate, and incorporate SCADA

Disadvantages

- Initial Cost

Opinion of Probable Construction Costs and Life Cycle Analysis

An opinion of probable construction cost was prepared for the alternative and is provided in Table 3-24. The estimate assumed four slide gates.

Table 3-24. Slide Gate Replacement Opinion of Probable Construction Cost

Description of Work	Amount
New Slide Gates	$84,000
Existing Headwork Concrete Repair	$5,000
Motorization	$20,000
Automation and SCADA	$8,000
Mobilization (@ 15%)	$17,550
Contingency (@ 30%)	$40,365
Engineering (10%)	$17,492
Total	**$192,407**

A 50-year life cycle cost analysis for the alternative is provided in Table 3-25. SCADA with an annual fee of $750/year was assumed and included in the operation and maintenance cost of life cycle cost analysis.

Table 3-25. Slide Gate Replacement 50-Year Life Cycle Analysis

Description of Work	Present Value (2020 Dollars)
Operation and Maintenance	$13,692
Rehabilitation/Overhaul	$1,451
Power	$3,651
Replacement	$0
Present Value Subtotal	$18,795
50-Year Present Worth[1]	**$211,201**

[1]Includes initial construction cost

3.7 Bank Stabilization

Bank stabilization options for the Bureau of Land Management (BLM) Upper Toston Recreation Area were developed, described and inserted into a pairwise ranking system during the early stages of this project (Appendix L). The goal of the initial assessment was to develop a wide range of alternatives for presentation to stakeholders. Eleven alternatives were developed and ranked based on eight criteria. The pairwise assessment allowed a quantitative analysis of the alternatives to determine the top three alternatives for future consideration.

BLM reviewed the options and selected their preference based on success at similar sites for past projects, precluding the need to develop additional alternatives further. BLM's preferred alternative recommendations are presented in Appendix M and summarized as follows.

- Utilize rock revetment by placing stone materials – with a low tolerance for movement – to stabilize the existing bank and restore missing sections of shoreline that have been lost to erosion. Materials that are adequately sized for stream and shoreline protection are strongly recommended. BLM also recommends placement of revetment materials at a minimum of ten feet outside of the existing Toston Dam Recreation Site shoreline. BLM recommends placing revetment materials at a minimum of 12 inches above the existing river elevation (full pool). It's also recommended that a new bank zone be established and gradually shaped upward to match or tie into the existing line and grade of the existing bank.
- Cap the rock revetment with 6 inches of aggregate base course and compact the material to 95 percent of maximum dry density. Aggregate base material is preferred since it's free draining and easy to shape and compact.
- Place and anchor a coyer log fence along the shoreline.
- Cap the aggregate base lift with topsoil and tie directly into the coyer log fence, keying the erosion structure in place. Revegetate the topsoil and coyer fence with hardy, native grasses or comparable materials. This area is generally vegetated with flexible woody stemmed plants such as willows, dogwood, elderberry, and low shrubs when utilizing bio-engineering techniques. Due to the known presence of beaver in the area and the proximity of the adjacent dam, the use of

woody stemmed plants should, at most, be sparingly used. Alternative vegetation is preference.

4 Permitting Requirements

4.1 Permitting Overview

Specific permitting requirements applicable to the project will depend on the conceptual design alternative selected for final design and associated impacts. Applicable permitting agencies and permits anticipated to apply to the work include the following:

- US Army Corps of Engineers
  - Section 404 permitting
  - Section 10 permitting
- Federal Energy Regulatory Commission (FERC)
  - Approval
- Montana Fish Wildlife and Parks
  - SPA 124 permit
- Broadwater County Conservation District
  - 310 permit
- Broadwater County
  - Floodplain Development Permit
- Montana Department of Environmental Quality
  - 318 authorization
  - MPDES General Permit for Stormwater Discharges
  - MPDES General Permit for Construction Dewatering
- DNRC
  - Montana Easement on Navigable Waters
  - Montana Water Use Act Change Authorization (applicability to the relocation of the headworks upstream will be evaluated)

For those alternatives involving work within the reservoir, including jetty removal, jetty reconstruction, channel stabilization, concrete sill/weir construction, bank realignment/reconstruction, etc., all those permits listed above except as specifically stated as excluded are anticipated to apply to the work.

5 Summary and Recommendations

Based on the alternatives presented in Section 3, the pairwise matrix for jetty replacement was updated and is included in Appendix N. The resulting top alternatives are:

1. Box Culvert
2. Riprap Jetty
3. FIBC/Grout Jetty

Upon closer examination it can be seen that the conceptual cost estimates for a 50-year life cycle are: $2.38M, $1.63M, and $1.30/$1.32M, respectively. However, due primarily to simpler design and construction complexity and impacts to the dam/hydropower intake risk, the **Box Culvert** is the recommended alternative. It should be noted that minor adjustments to the weighted scoring system changes the preferred alternative.

It is recommended that the existing slide gates be replaced in kind as they have reached the end of their design life. Final gate design would be based on the jetty alternative selected and effectiveness of the alternative at controlling floating debris and sediment transport and deposition, with different types and configurations of gates considered as applicable.

Bank stabilization at the BLM Upper Toston Recreation Area would incorporate BLM preference with site specific details added. In general, the recommended bank stabilization will include a rock base capped with an aggregate mix then topped with a growth media. Coir logs and/or coir fabric would be utilized, and the site would be revegetated.

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7 Acronyms

ACB	Articulating Concrete Block
BLM	Bureau of Land Management
BWMWUA	Broadwater Missouri Water Users Association
CAU	Concrete Armor Units
cfs	cubic feet per second
CORS	Continuously Operation Reference Stations
DTM	digital terrain model
FERC	Federal Energy Regulatory Commission
FIBC	Flexible Intermediate Bulk Container
MW	Megawatt
NAVD88	North American Vertical Datum of1988
NOAA	National Oceanic and Atmospheric Administration
OPUS	Online Positioning User Service
PER	Preliminary Engineering Report
PLC	programmable logic control
RAS	US Army Corps of Engineers Hydraulic Engineering Center's River Analysis System hydraulic modeling software, Version 5.0.7
SCADA	Supervisory Control and Data Acquisition
SWPB	State Water Projects Bureau
UMS	Utility Mapping Services Incorporated
WGS84	World Geodetic System 1984

Appendix A. Preliminary Jetty Alternatives Matrix

Criteria	Definition
Operation and Maintenance Requirements	Level of effort to operate and maintain the facilities
Floating Debris Susceptibility	Potential for impacts to the functionality or integrity of the facilities due to floating debris loading/collection
Geomorphic Susceptibility	Potential for impacts to the functionality or integrity of the facilities due to erosion, instability, and sediment transport/deposition (geomorphic processes)
Hydropower Intake Impacts	Potential for impacts to the hydropower intake due to channel bed instablity and material shedding into the channel in front of the hydropwer intake screens
Structure Replacement Frequency	Frequency of structure replacement or major overhauls/refurbishment (structure design life/longevity)
Construction Complexity	Complexity of the design and amount of specialty skills and/or equipment required during construction, the extent of work within the reservoir and dewatering requirements, the extent of modifications to existing facilities
Construction Cost	Material and labor costs for overall project construction
Permitting Requirements	Number of permits required to mitigate impact of construction on the riverine environment
Design Effort	Level of effort to complete final design
Life Cycle Cost	Cost of project design, construction, operation and maintenance over life of project (consistent timeframe for comparison between alternatives)
Impact to Dam/Project	Level of structural or permitting risk to the Broadwater Dam Project.

		1 Operation and Maintenance Requirements	2 Floating Debris Susceptibility	3 Geomorphic Susceptibility	4 Hydropower Intake Impacts	5 Structure Replacement Frequency	6 Construction Complexity	7 Construction Cost	8 Permitting Requirements	9 Design Effort	10 Life Cycle Cost	11 Impact to Dam/Project			Percent	Rank
1	Operation and Maintenance Requirements		4	4	4	4	5	4	5	4	3	1	1	Operation and Maintenance Requirements	18%	1
2	Floating Debris Susceptibility	2		4	3	4	5	4	5	4	3	1	2	Floating Debris Susceptibility	16%	2
3	Geomorphic Susceptibility	2	2		2	4	5	4	5	4	3	1	3	Geomorphic Susceptibility	14%	4
4	Hydropower Intake Impacts	2	3	4		4	5	4	5	4	4	1	4	Hydropower Intake Impacts	16%	2
5	Structure Replacement Frequency	2	2	2	2		4	3	5	4	2	1	5	Structure Replacement Frequency	12%	5
6	Construction Complexity	1	1	1	1	2		3	5	3	2	1	6	Construction Complexity	8%	7
7	Construction Cost	2	2	2	2	3	3		5	4	2	1	7	Construction Cost	11%	6
8	Permitting Requirements	1	1	1	1	1	1	1		4	1	1	8	Permitting Requirements	4%	8
9	Design Effort	2	2	2	2	2	3	2	2		2	1	9	Design Effort	10%	9
10	Life Cycle Cost	3	3	3	2	4	4	4	5	4		1	10	Life Cycle Cost	17%	3
11	Impact to Dam/Project	5	5	5	5	5	5	5	5	5	5		11	Impact to Dam/Project	24%	1

Scoring scale:

Rate the importance of the activity in the row relative to activity in the column where they intersect.

If the row is much less important than the column, enter 1

If the row is less important than the column, enter 2

If the row has the same importance as the column, enter 3

If the row is more important than the column, enter 4

If the row is much more important than the column, enter 5

Final Pairwise

		Broadwater Power Project Jetty Replacement and Erosion Control (Jetty Replacement)												
		Operation and Maintenance Requirements	Floating Debris Susceptibility	Geomorphic Susceptibility	Hydropower Intake Impacts	Structure Replacement Frequency	Construction Complexity	Construction Cost	Permitting Requirements	Design Effort	Life Cycle Cost	Impact to Dam/Project	Weighted Average	Rank
Alternative	**Alternative Description**	**0.18**	**0.16**	**0.14**	**0.16**	**0.12**	**0.08**	**0.11**	**0.04**	**0.10**	**0.16**	**0.24**	-	
Rebuild Existing Jetty with Rock Riprap or Precast Concrete Armor Units (CAUs)	Remove the exisiting jetty and reconstruct the jetty on a new alignment utilizing rock riprap, installed on a 2:1 slope or CAUs installed on up to a 1.5:1 slope. Realignment of the irrigation canal and/or roadway may be required. Install a floating debris barrier across the jetty inlet. Alternative jetty configurations could reduce the need for a debris barrier.	3	4	3	4	5	2	2	3	4	3	5	5.42	3
Rebuild Existing Jetty with Articulating Concrete Block Mats (ACBMs) or Gabions	Remove the existing jetty and reconstruct the jetty on a new alignment utilizing ACBMs or gabion basktes. Realignment of the irrigation canal and/or roadway may be required. Install a floating debris barrier across the jetty inlet. Alternative jetty configurations could reduce the need for a debris barrier.	3	4	3	5	4	2	3	3	4	4	5	5.73	2
Rebuild Existing Jetty with Gabions (w/ no Jetty Inlet provided)	Remove the existing jetty and reconstruct the jetty on a new or the existing alignment utilizing gabion baskets. Extend the jetty across the entire opening and utilize rock fill sized to to allow canal flows to pass through the gabion baskets (no separate jetty inlet). Air sparging lines or other methods could be utilized to remove small debris.	1	2	3	5	3	2	2	3	3	3	5	4.57	5
Sheet Pile Wall	Remove the existing jetty and reconstruct the jetty on a new alignment utilizing a single or double sheet pile wall. Install a floating debris barrier across the jetty inlet. Alternative jetty configurations could reduce the need for a floating debris barrier.	4	4	3	5	4	1	2	3	2	2	2	4.49	6
Debris Barrier	Remove either the entire jetty or a portion of the existing jetty and stabilize the channel at the removal location using an underwater concrete revetment system, such as an ACBMs, or other means. Install a floating debris barrier. The debris barrier could also include submerged underwater debris screens. Additional support for the debris barrier such as piles may be required.	4	4	4	5	3	4	4	4	4	3	5	6.10	1
Enhanced Mechanical Removal	Remove the existing jetty or a portion of the existing jetty and stabilize the channel at the removal location using an underwater concrete revetment system, such as an ACBMs, or other means. Install a trash rack and mechanical trash rake system in front of the irrigation headworks. Other alternative mechanical trash removal systems could be considered.	1	1	2	5	1	3	3	5	2	1	5	3.89	7
Debris Deflector or Trash Rack	Remove the existing jetty or a portion of the existing jetty and stabilize the channel at the removal location using an underwater concrete revetment system, such as an ACBMs, or other means. Install a debris deflector or trash rack and a floating debris barrier to protect and deflect debris away from irrigation headworks. Various debris rack or deflector configurations and designs could be considered.	1	1	2	3	5	4	5	4	3	2	5	4.57	5
Floating Jetty	Remove the existing jetty or a portion of the existing jetty and stabilize the channel at the removal location using an underwater concrete revetment system, such as an ACBMs, or other means. Install a floating jetty system which could include a submerged underwater debris screen. Additional support for the floating jetty such as piles may be required.	2	3	2	4	2	4	3	4	4	3	5	2.85	10

Realign Bank and Relocate Irrigation Headworks Upstream	Remove the existing jetty or a portion of the existing jetty and stabilize the channel at the removal location using an underwater concrete revetment system, such as an ACBMs, or other means. Realign the bank and relocate the irrigation headworks and canal upstream in the realigned bank. Install a floating debris barrier in front of the irrgation headworks if warranted.	5	5	2	4	5	1	1	1	4	4	5	**3.46**	**8**
Soldier Pile Wall	Remove the existing jetty or a portion of the existing jetty and stabilize the channel at the removal location using an underwater concrete revetment system, such as an ACBMs, or other means. Construct a soldier pile wall. Different wall system options could include fixed or removeable/adjustable systems, and could incorporate floating and/or submerged elements for handling debris.	3	3	3	4	3	2	2	3	2	3	2	**2.96**	**9**
Super Sacks or Geotextile Container	Remove the existing jetty or a portion of the existing jetty and stabilize the channel at the removal location using an underwater concrete revetment system, such as an ACBMs, or other means. Construct a new jetty using super sacks or geotextile tubes filled with sand. Install a floating debris barrier across the jetty inlet. Alternative jetty configurations could reduce the need for a debris barrier.	2	3	3	2	1	5	4	4	3	4	5	**2.74**	**11**
Do Nothing	Leave the current facilities as-is.	1	1	2	1	1	5	5	5	5	3	5	**2.10**	**12**

Key:
Scale 1 to 5
1 = Poor/Low Value
5 = Excellent/High Value

Appendix B. Preliminary Slide Gate Alternatives Matrix

		1 Operation and Maintenance Requirements	2 Floating Debris Susceptibility	3 Geomorphic Susceptibility	4 Irrigation Diversion Variability	5 Structure Replacement Frequency	6 Construction Complexity	7 Construction Cost	8 Permitting Requirements	9 Design Effort	10 Life Cycle Cost	11 Impact to Dam/Project			Percent	Rank
1	Operation and Maintenance Requirements		3	4	4	4	5	4	5	4	3	1	1	Operation and Maintenance Requirements	17%	2
2	Floating Debris Suseptibility	3		4	4	4	5	4	5	4	3	1	2	Floating Debris Suseptibility	17%	2
3	Geomorphic Suseptibility	2	2		4	4	5	4	5	4	3	1	3	Geomorphic Suseptibility	15%	5
4	Irrigation Diversion Variability	2	2	2		4	5	4	5	4	4	1	4	Irrigation Diversion Variability	14%	6
5	Structure Replacement Frequency	2	2	2	2		4	3	5	4	2	1	5	Structure Replacement Frequency	12%	7
6	Construction Complexity	1	1	1	1	2		4	5	4	2	1	6	Construction Complexity	9%	10
7	Construction Cost	2	2	2	2	3	2		4	4	2	1	7	Construction Cost	10%	8
8	Permitting Requirements	1	1	1	1	1	1	2		4	2	1	8	Permitting Requirements	5%	11
9	Design Effort	2	2	2	2	2	2	2	2		2	1	9	Design Effort	10%	9
10	Life Cycle Cost	3	3	3	2	4	4	4	4	4		1	10	Life Cycle Cost	16%	4
11	Impact to Dam/Project	5	5	5	5	5	5	5	5	5	5		11	Impact to Dam/Project	24%	1

Scoring scale:

Rate the importance of the activity in the row relative to activity in the column where they intersect.

If the row is much less important than the column, enter 1

If the row is less important than the column, enter 2

If the row has the same importance as the column, enter 3

If the row is more important than the column, enter 4

If the row is much more important than the column, enter 5

Criteria	Definition
Operation and Maintenance Requirements	Level of effort to operate and maintain the facilities
Floating Debris Suseptibility	Potential for impacts to the functionality or integrity of the facilities due to floating debris loading/collection and inability of the facilities to pass floating debris
Geomorphic Suseptibility	Potential for impacts to the functionality or integrity of the facilities due to erosion, instability, and sediment transport/deposition (geomorphic processes) and inability of the facilities to pass sediment
Irrigation Diversion Variability	Potential variability in irigation water diversions (flow rates) due to changing upstream water levels and conditions and associated effort required to make water diversion adjustments
Structure Replacement Frequency	Frequency of structure replacement or major overhauls/refurbishment (structure design life/longevity)
Construction Complexity	Complexity of the design and amount of specialty skills and/or equipment required during construction, the extent of work within the reservoir and dewatering requirements, the extent of modifications to existing facilities
Construction Cost	Material and labor costs for overall project construction
Permitting Requirements	Number of permits required to mitigate impact of construction on the riverine environment
Design Effort	Level of effort to complete final design
Life Cycle Cost	Cost of project design, construction, operation and maintenance over life of project (consistent timeframe for comparison between alternatives)
Impact to Dam/Project	Level of structural or permitting risk to the Broadwater Dam Project.

Final Pairwise

		Broadwater Power Project Jetty Replacement and Erosion Control (Slide Gate Replacement)												
		Operation and Maintenance Requirements	Floating Debris Suseptibility	Geomorphic Suseptibility	Irrigation Diversion Variability	Structure Replacement Frequency	Construction Complexity	Construction Cost	Permitting Requirements	Design Effort	Life Cycle Cost	Impact to Dam/Project	Weighted Average	Rank
Alternative	**Alternative Description**	**0.17**	**0.17**	**0.15**	**0.14**	**0.12**	**0.09**	**0.10**	**0.05**	**0.10**	**0.16**	**0.24**	**-**	
Replace Slide Gates and Rehabilitate Headworks Structure	Replace the existing slide gates with new manually operated slide gates. One or more of the slide gates could optionally be motorized. Rehabilitate the exisiting headworks structure, including any warranted concrete repair-work or modifications.	5	1	4	2	3	4	4	4	4	4	5	**5.46**	**2**
Replace Slide Gates with Automation and Rehabilitate Heaworks Structure	Replace the existing slide gates with new slide gates which include a combination of manually operated and motorized gates. Incorporate gate automation to maintain consistent water deliveries. SCADA incorporation could also be considered and may faciliate remote operation. Rehabilitate the existing headworks structure, including any warranted concrete repair-work or modifications.	4	1	4	5	3	3	3	4	4	4	5	**5.53**	**1**
Replace Slide Gates with Different Gate Configuration with Automation and Rehabilitate Headworks	Replace the existing slide gates with a new configuration of gates which could include undershot gates and overshot gates. Automation and SCADA could also be incorporated. Rehabilitate the existing headworks structure, including any warranted concrete repair-work or modifications.	3	3	3	5	2	3	3	4	3	3	5	**5.17**	**3**
Realign Bank and Relocate Irrigation Headworks Upstream	Realign the bank and relocate the irrigation headworks and canal upstream in the realigned bank. Construct a new headworks structure and conveyance to tie into the existing box culvert. Realignment of the roadway may be required.	4	4	2	4	5	1	1	1	2	3	5	**4.96**	**4**
Relocate Irrigation Headworks Downstream	Relocate the irrigation headworks downstream of the existing box culvert outlet. Construct a new headwork and wasteway structure. Rehabilitate the existing headworks structure to facilitate its use for debris control and shutting of flows to the canal (using stoplogs/ bulkheads). This alternative likely is not feasible depending on the box culvert profile and ancipated extent of required modifications.	2	1	2	4	5	1	1	2	2	2	5	**3.98**	**7**
Reconstruct Headworks in Place	Reconstruct the headworks in place. Long crested weir. At an angle.	4	1	4	3	5	2	2	3	2	2	5	**4.73**	**6**
Do Nothing	Leave the current facilities as-is.	1	1	4	1	1	5	5	5	5	5	5	**4.89**	**5**

Key:
Scale 1 to 5

1 = Poor/Low Value

5 = Excellent/High Value

Appendix C. Preliminary Bank Stabilization Alternatives Matrix

Criteria	Definition
Operation and Maintenance Requirements	Level of effort to operate and maintain the facilities
Recreational and Aesthetic Impacts	Recreational and aesthic impacts due to the facilities, including toward use of the reservoir, access to the reservoir, and campground use
Environmental Impacts	Environmental impacts due to the facilities, including towards vegetation growth and wildlife and fish habitat.
Geomorphic Susceptibility	Potential for impacts to the functionality or integrity of the facilities due to erosion, instability, and sediment transport/deposition (geomorphic processes)
Structure Replacement Frequency	Frequency of structure replacement or major overhauls/refurbishment (structure design life/longevity)
Construction Complexity	Complexity of the design and amount of specialty skills and/or equipment required during construction, the extent of work within the reservoir and dewatering requirements, the extent of modifications to existing facilities
Construction Cost	Material and labor costs for overall project construction
Permitting Requirements	Number of permits required to mitigate impact of construction on the riverine environment

		1 Operation and Maintenance Requirements	2 Recreational and Aesthetic Impacts	3 Environmental Impacts	4 Geomorphic Susceptibility	5 Structure Replacement Frequency	6 Construction Complexity	7 Construction Cost	8 Permitting Requirements			Percent	Rank
1	Operation and Maintenance Requirements		4	3	2	3	5	4	5	1	Operation and Maintenance Requirements	15%	2
2	Recreational and Aesthetic Impacts	2		3	1	3	5	4	5	2	Recreational and Aesthetic Impacts	14%	4
3	Environmental Impacts	3	3		1	3	5	4	5	3	Environmental Impacts	14%	3
4	Geomorphic Susceptibility	4	5	5		5	5	5	5	4	Geomorphic Susceptibility	20%	1
5	Structure Replacement Frequency	3	3	3	1		4	3	5	5	Structure Replacement Frequency	13%	5
6	Construction Complexity	1	1	1	1	2		3	5	6	Construction Complexity	8%	7
7	Construction Cost	2	2	2	1	3	3		5	7	Construction Cost	11%	6
8	Permitting Requirements	1	1	1	1	1	1	1		8	Permitting Requirements	4%	8

Scoring scale:

Rate the importance of the activity in the row relative to activity in the column where they intersect.

If the row is much less important than the column, enter 1

If the row is less important than the column, enter 2

If the row has the same importance as the column, enter 3

If the row is more important than the column, enter 4

If the row is much more important than the column, enter 5

Final Pairwise

		Broadwater Power Project Jetty Replacement and Erosion Control (Jetty Replacement)									
		Operation and Maintenance Requirements	Recreational and Aesthetic Impacts	Environmental Impacts	Geomorphic Susceptibility	Structure Replacement Frequency	Construction Complexity	Construction Cost	Permitting Requirements	Weighted Average	Rank
Alternative	Alternative Description	0.15	0.14	0.14	0.20	0.13	0.08	0.11	0.04	-	
Signage and Access Restrictions (Preventative Methods)	Install signage and/or fencing to restrict reservoir activity (e.g., no-wake signs) and/or access along the banks.	5	2	4	3	4	5	5	5	3.91	4
Construct Spur Dikes, Vanes, or Bendway Weirs	Construct vanes, spur dikes, or bendway weirs utilizing rock riprap, precast concrete armor units (CAUs), or other materials to redirect flows.	4	1	3	4	5	1	1	1	2.88	10
Construct Revetment with Rock Ripap, Articulating Concrete Block Mats (ACBMs), or Gabions	Construct a revetment utilizing rock riprap, ACBMs, gabions, or other materials to armor the bank. The revetment could also incorporate vegetation.	5	3	4	5	5	3	2	2	3.97	3
Construct Revetment with Shotcrete or Concrete	Construct a revetment utilizing shotcrete, concrete, fabric or geotextile/geosynthetic formed concrete mattresses, or other materials to armor the bank.	5	1	1	4	4	2	2	2	2.85	11
Construct Riprap Toe Protection with Bioengineered Bank	Construct bank toe protection with rock riprap. Construct a bioengineered bank above the stone toe using soil encapsulated fabric wraps with biodegradable coir fabric.	5	4	4	5	5	3	2	2	4.11	1
Construct Longitudinal Peak Stone Toe with Bioengineered Bank	Construct a longitudinal peak stone toe utilizing rock riprap. Construct a bioengineered bank above the stone toe.	4	4	4	3	3	3	3	2	3.39	5

Construct Bioengineered Bank	Reconstruct the bank as a bioengineered bank utilizing wrapped soil lifts planted with vegetation.	3	4	4	3	3	3	3	3	**3.28**	**7**
Revegetate Bank	Protect the bank utilizing a temporary degradable rolled erosion control product (RECP) and revegetate the bank utilizing appropriate plantings and trees.	2	5	4	2	2	4	5	5	**3.31**	**6**
Construct Revetment using Native Material	Construct a revetment utilizing boulders, logs, rootwads, or other native materials. Revegetate the bank or construct a bioengineered bank above the revetment.	3	3	5	4	3	2	2	2	**3.26**	**8**
No Wake Zone	Move existing barrier upstream and add "No Wake Zone" signage.	5	4	3	3	4	5	5	5	**4.04**	**2**
Do Nothing	Leave the current facilities as-is.	3	1	3	1	5	5	5	5	**3.05**	**9**

Key:
Scale 1 to 5
1 = Poor/Low Value
5 = Excellent/High Value

Appendix D. DNRC Comments

DNRC Discussion of Jetty Replacement Alternatives Summary- April 17, 2020

Bank Erosion-

The bank erosion alternatives were not discussed because the BLM will be taking the lead on this portion of the project.

Jetty Options-

During the review of the proposed alternatives and their associated rankings the team noted some difficulty in comparing the different alternatives. In some cases, the options proposed were essentially the same solution but with an alternative material. The team felt at this level we should be looking at the general alternatives. Once we have determined which of the general alternatives we need to pursue, we can start looking at the various material options.

The following is a list of the general alternatives the team decided needed further analysis. Some of the alternatives were grouped together because the evaluation team determined they were the same general design with an alternative material. Some of the alternatives are likely going to be eliminated due to cost or complexity, but the analysis needs to be performed so the process for their elimination is documented. The order of the alternatives below is based on the pairwise rankings provided by HDR and not DNRC prioritization. The final prioritization of the options should be performed after additional analysis.

The review team determined that in order to determine life cycle cost, a project life needed to be determined. A project lifespan of 50-years was chosen for life cycle analysis purposes.

Discussion of the various alternatives does not specify whether construction would require dewatering of the jetty area or a reduction in the reservoir level. This should be included in the analysis because there is a significant financial impact to the DNRC if the hydropower plant must cease production to facilitate construction.

1. Floating Debris Barrier- PWR (1, 10)

This alternative included the removal of the existing jetty and installing a floating debris barrier. It also included the installation of under water revetment systems, but there were some questions on whether this was needed if the existing jetty was fully removed. A floating debris barrier with a submerged screen would be effective at removing floating and semi submerged materials.

A floating debris barrier would not be effective in controlling sediment or fully submerged debris. The evaluation for this option should include an analysis to determine if sediment control is needed given the current amount of sediment in the canal, if sloping the area where the jetty currently located towards the power plant intake would eliminate the sediment issue, or if a weir wall should be installed. The weir wall was not part of any of the other general alternatives, so it was included with this one.

Cost analysis for this alternative should include a range of cost based on the various debris barrier systems.

2. Gravity Jetty- PWR (2,3,4,11)

This alternative included removal of the existing jetty and replacement of the jetty with gravity type jetty. Various jetty material options i.e. rip rap, concrete blocks, ACBMs, super sacks, gabion baskets, geotextile tubes or mats, would likely have similar configurations and functionality. It is assumed the existing jetty needs to be fully removed because it does not provide a competent foundation for any of the reconstruction alternatives. Analysis of which material used to construct a gravity style jetty should be performed only if this alternative is chosen as the preferred alternative.

Cost analysis for this alternative should include a range of costs based on the various materials proposed. All the alternative descriptions in the pairwise rankings also include a floating debris barrier at the inlet area. Anchoring systems and barrier replacement costs should be included in the analysis.

3. Pile Jetty- PWR (6, 9)

This alternative includes the removal of the exiting jetty and replacement of the jetty with sheet pile or soldier pile wall. It is assumed for this analysis the configuration of the pile walls would be similar. It is also assumed the foundation analysis needed to determine if a soldier or sheet pile wall is constructible is the same.

Cost analysis for this alternative should include a range of costs based on the type of wall proposed. Discussion regarding floating debris barrier verses alternative pile configurations can be performed as part of a more in-depth analysis if this alternative is determined to be the preferred alternative.

4. Trash Rack Immediately Upstream of Current Gate Location (Enhanced Mechanical Removal)- PWR (7)

This alternative includes removal of the existing jetty and installation of a trash rack near the existing gate location. It is assumed this alternative does not include replacement of the jetty, so there would be increased floating debris accumulating at the canal intake. A mechanical handling system would be needed to handle the increased debris load. Possible debris handling options include a dedicated trash rake, upgrades to existing mobile equipment, acquisition of mobile handling equipment, and traveling screen systems.

Cost analysis for this alternative should include a range of costs based on debris handling equipment and the associated manpower required. Discussions regarding the orientation and size of racks and screens can be performed as par of a more in-depth analysis if this alternative is determined to be the preferred alternative.

5. Realign Bank and Relocated Irrigation Headworks Upstream- PWR (8)

This alternative included the removal of the existing jetty, realignment of the roadway and canal, and relocation of the canal inlet and associated headgate upstream. Discussion regarding headgate and trash rack configurations that could be incorporated into this alternative can be performed as part of a more in-depth analysis if this alternative is determined to be the preferred alternative.

6. No Action- PWR (12)

This alternative does not change the current configuration and operation of the site. Existing issues currently experienced would continue.

This alternative needs to be included in the alternatives analysis because it will be included as part of future MEPA documentation. Operation and maintenance cost associated with this alternative should also be determined so they can be compared with the life cycle cost of other alternatives over the 50-year lifespan of the project.

Gate Options-

During the review of the proposed alternatives and their associated rankings the team noted some difficulty in comparing the different alternatives. The team felt at this level we should be looking at the general alternatives. Once we have determined which of the general alternatives we need to pursue, we can start looking at the various gate options.

The following is a list of the general gate alternatives the team decided needed further analysis. Some of the alternatives were grouped together because the evaluation team determined they were the same general design. Some of the alternatives are likely going to be eliminated due to cost or complexity, but the analysis needs to be performed so the process for their elimination is documented. The order of the alternatives below is based on the pairwise rankings provided by HDR and not DNRC prioritization. The final prioritization of the options should be performed after additional analysis.

The review team determined that in order to determine life cycle cost, a project life needed to be determined. A project lifespan of 50-years was chosen for life cycle analysis purposes.

Discussion of the various alternatives does not specify whether construction would require dewatering of the jetty area or a reduction in the reservoir level. This should be included in the analysis because there is a significant financial impact to the DNRC if the hydropower plant must cease production to facilitate construction.

1. Replace Headgate in Existing Location -

This alternate includes replacing the headgate in its current position or moving it a short distance upstream. The analysis to determine the type, number and automation of the gate(s) would be performed only if this alternative is chosen as the preferred alternative. A range of costs of the various gate alternatives should be included in the analysis but it is assumed the gate costs for the three possible headgate locations alternatives should be similar.

2. Move Headgate Down Canal -

This alternate includes replacing the headgate in a location down canal from the existing headgate and culvert location. The analysis to determine the type, number and automation of the gate(s) would be performed only if this alternative is chosen as the preferred alternative. A range of costs of the various gate alternatives should be included in the analysis but it is assumed the gate costs for the three possible headgate locations alternatives should be similar.

3. Move Headgate Upstream-

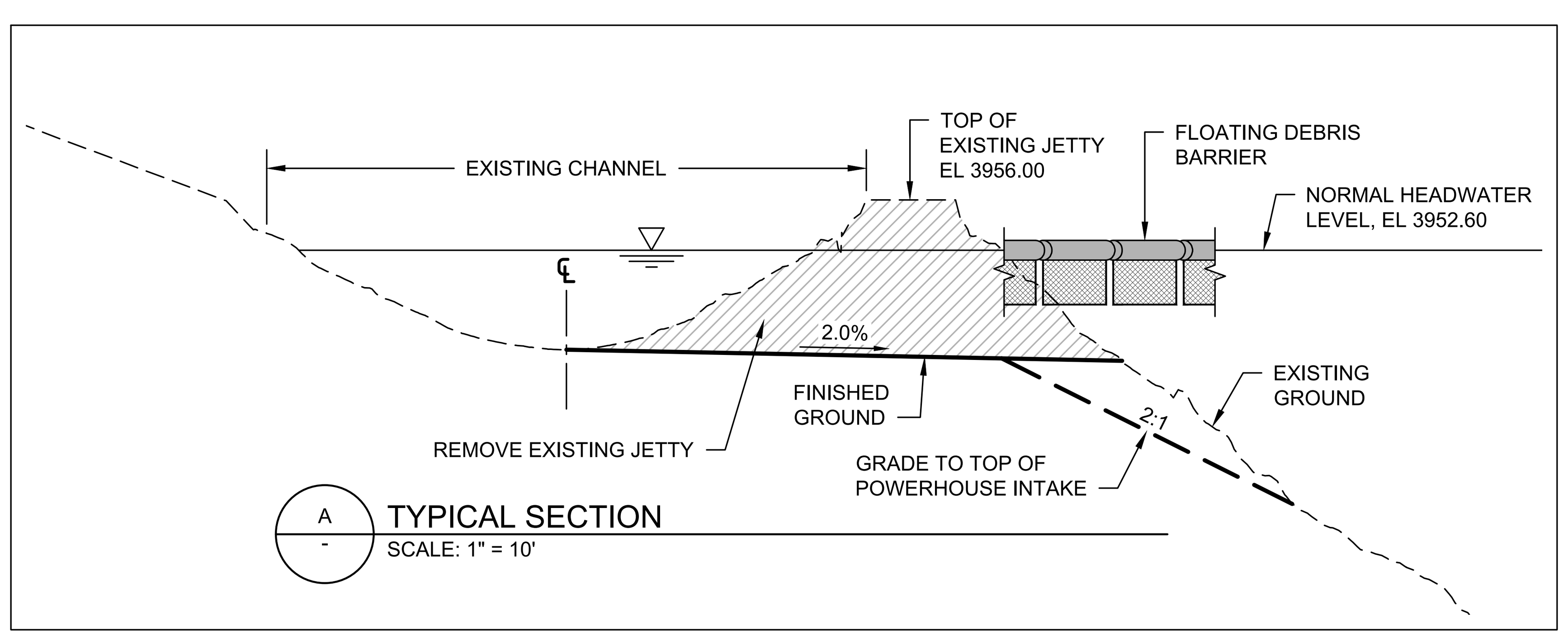
This alternate includes replacing the headgate in a location upstream from the existing headgate and culvert location. This alternative is closely linked to the Realign Bank and Relocated Irrigation Headworks Upstream- PWR (8) in the Jetty Option analysis. The analysis to determine the type, number and automation of the gate(s) would be performed only if this alternative is chosen as the preferred alternative. A range of costs of the various gate alternatives should be included in the analysis but it is assumed the gate costs for the three possible headgate locations alternatives should be similar.

4. No Action-

The no action alternative for the gate options is included in the no action alternative for the Jetty Options.

Appendix E. Floating Debris Barrier Conceptual Layout

1 2 3 4 5 6 7 8



A TYPICAL SECTION
SCALE: 1" = 10'

D C B A

HDR

ISSUE	DATE	DESCRIPTION

PROJECT MANAGER	D. MARCH
CIVIL 1	D. MARCH
CIVIL 2	
DRAWN BY	
PROJECT NUMBER	10214954

MONTANA DNRC

Toston, Montana

DNRC

Broadwater Jetty Improvements

2020

ALTERNATIVE 1
FLOATING DEBRIS BARRIER

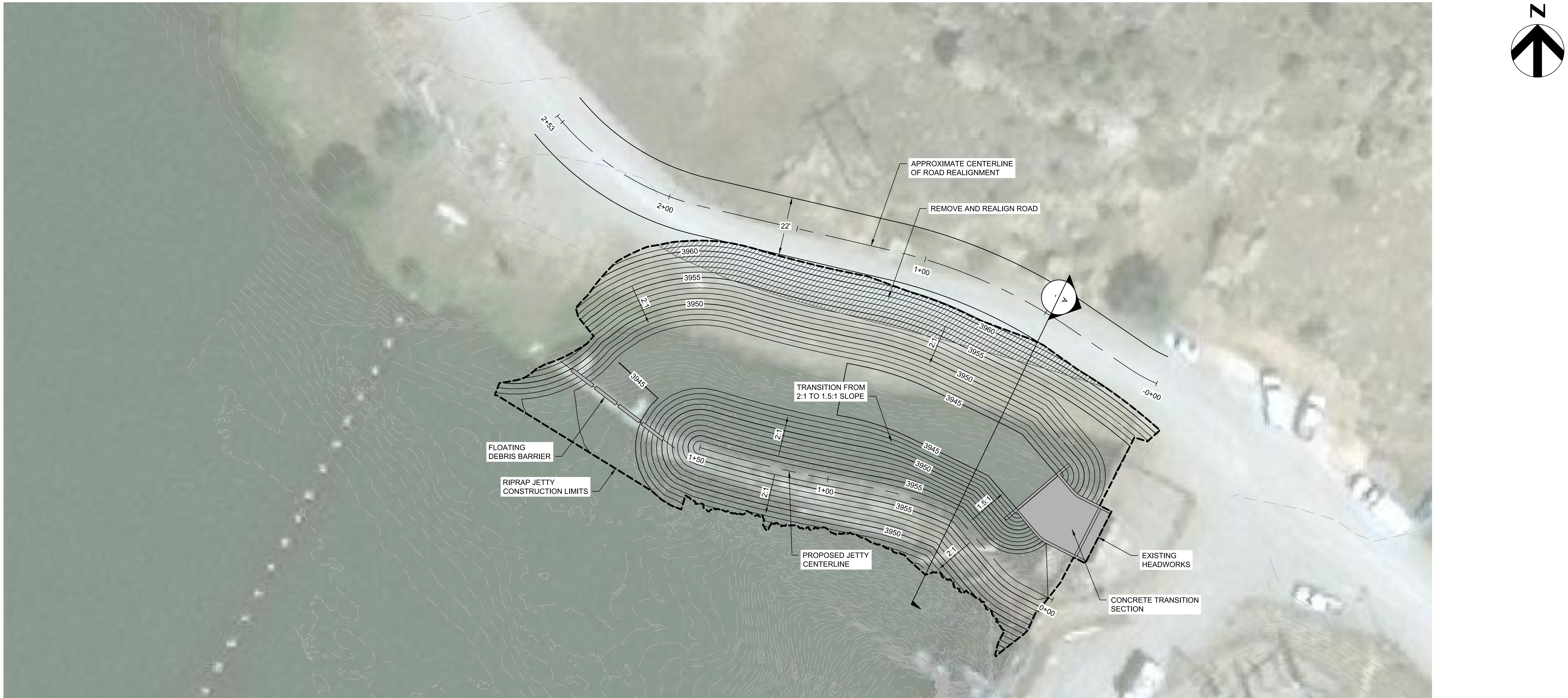
0 1" 2"

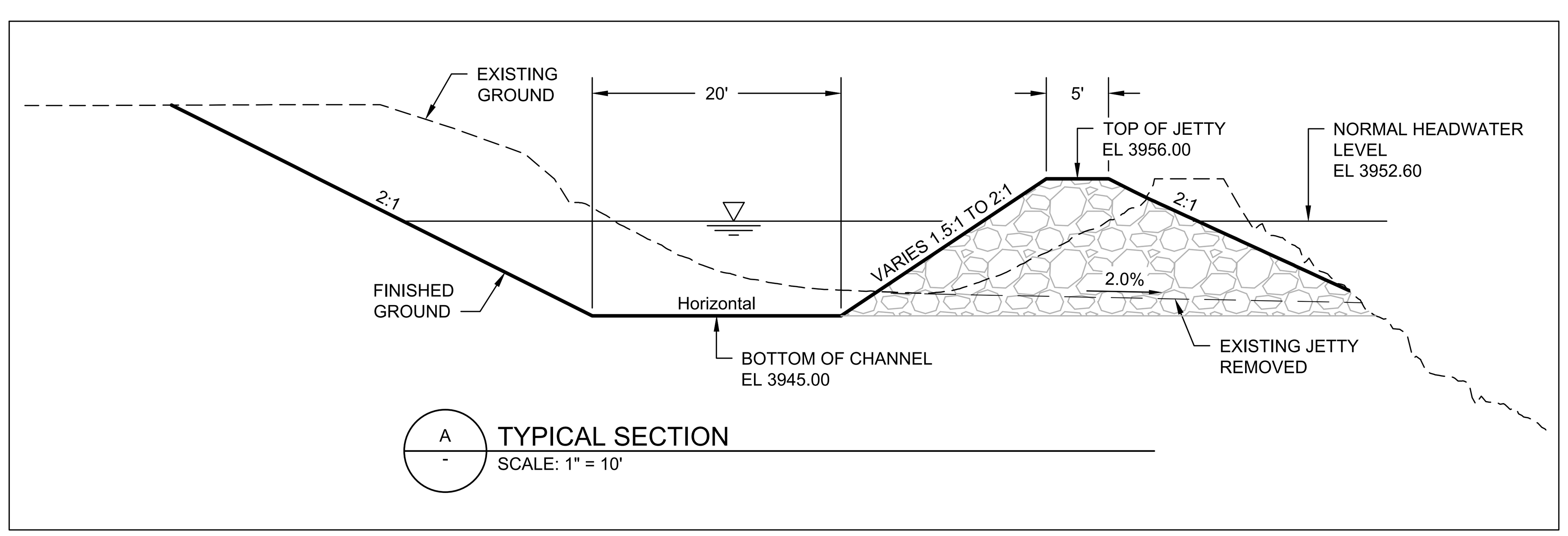
FILENAME 01C-ALT1.dwg

SCALE 1" = 20'-0"

SHEET 01C-ALT1

Appendix F. Riprap Jetty Conceptual Layout





A
TYPICAL SECTION
SCALE: 1" = 10'

HDR

ISSUE	DATE	DESCRIPTION

PROJECT MANAGER	D. MARCH
CIVIL 1	D. MARCH
CIVIL 2	
DRAWN BY	
PROJECT NUMBER	10214954

MONTANA DNRC

Toston, Montana

DNRC

Broadwater Jetty Improvements

2020

ALTERNATIVE 2
RIPRAP JETTY

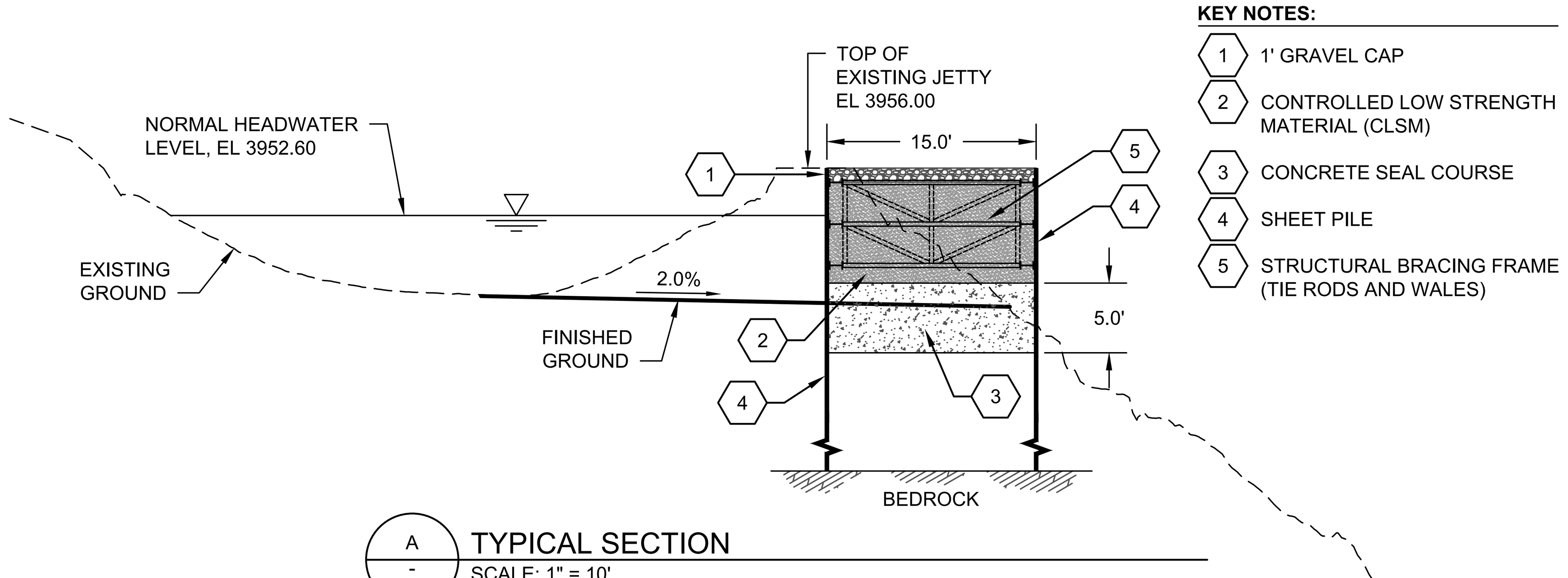
0 1" 2"

FILENAME 01C-ALT2.dwg

SCALE 1" = 20'-0"

SHEET 01C-ALT2

Appendix G. Sheet Pile Jetty Conceptual Layout



A TYPICAL SECTION
SCALE: 1" = 10'

KEY NOTES:

1. 1' GRAVEL CAP
2. CONTROLLED LOW STRENGTH MATERIAL (CLSM)
3. CONCRETE SEAL COURSE
4. SHEET PILE
5. STRUCTURAL BRACING FRAME (TIE RODS AND WALES)

HDR

ISSUE	DATE	DESCRIPTION

PROJECT MANAGER	D. MARCH
CIVIL 1	D. MARCH
CIVIL 2	
DRAWN BY	
PROJECT NUMBER	10214954

MONTANA DNRC

DNRC

Broadwater Jetty Improvements

Toston, Montana

2020

ALTERNATIVE 3
SHEET PILE JETTY

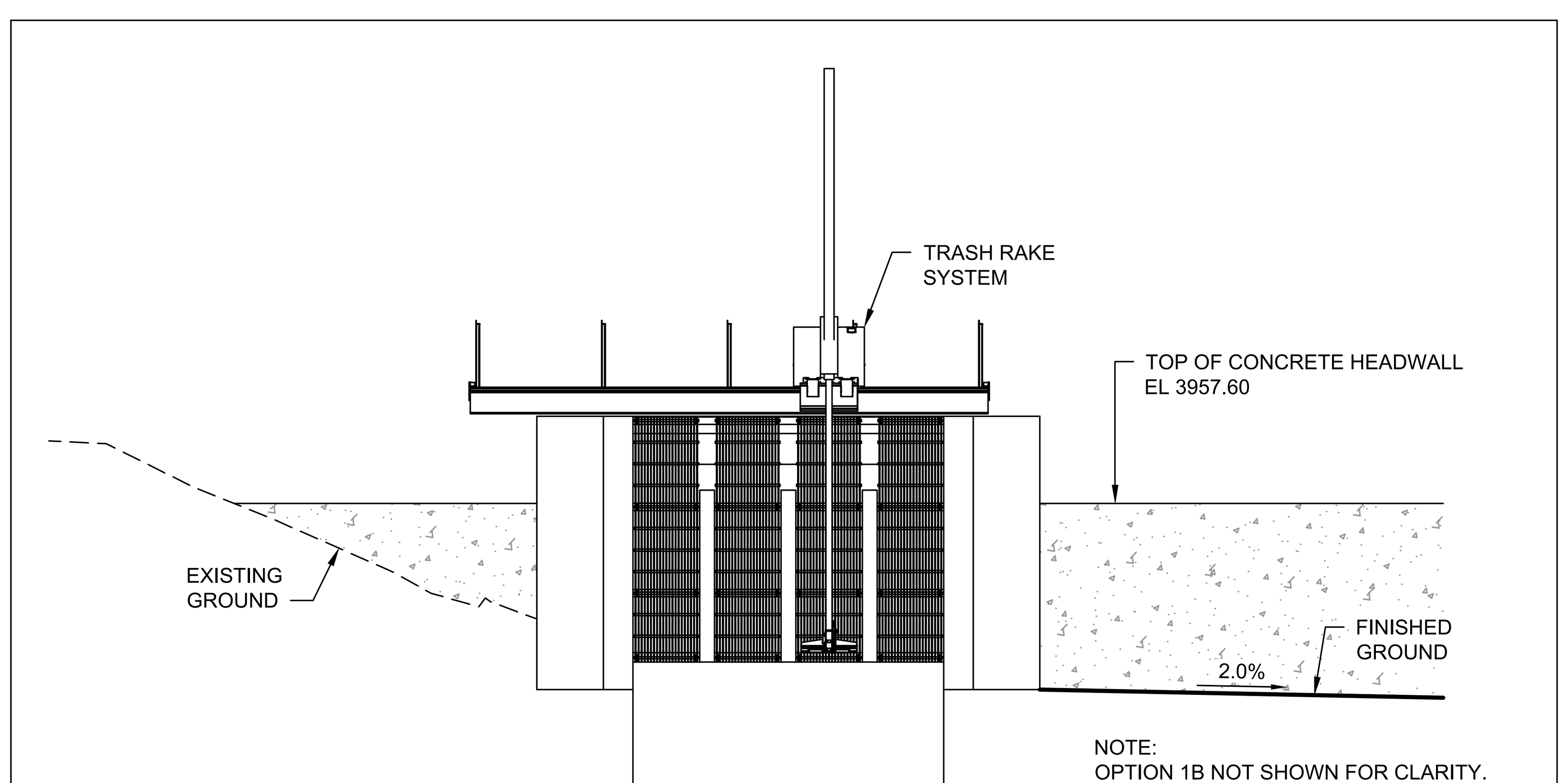
0 1" 2"

FILENAME 01C-ALT3.dwg

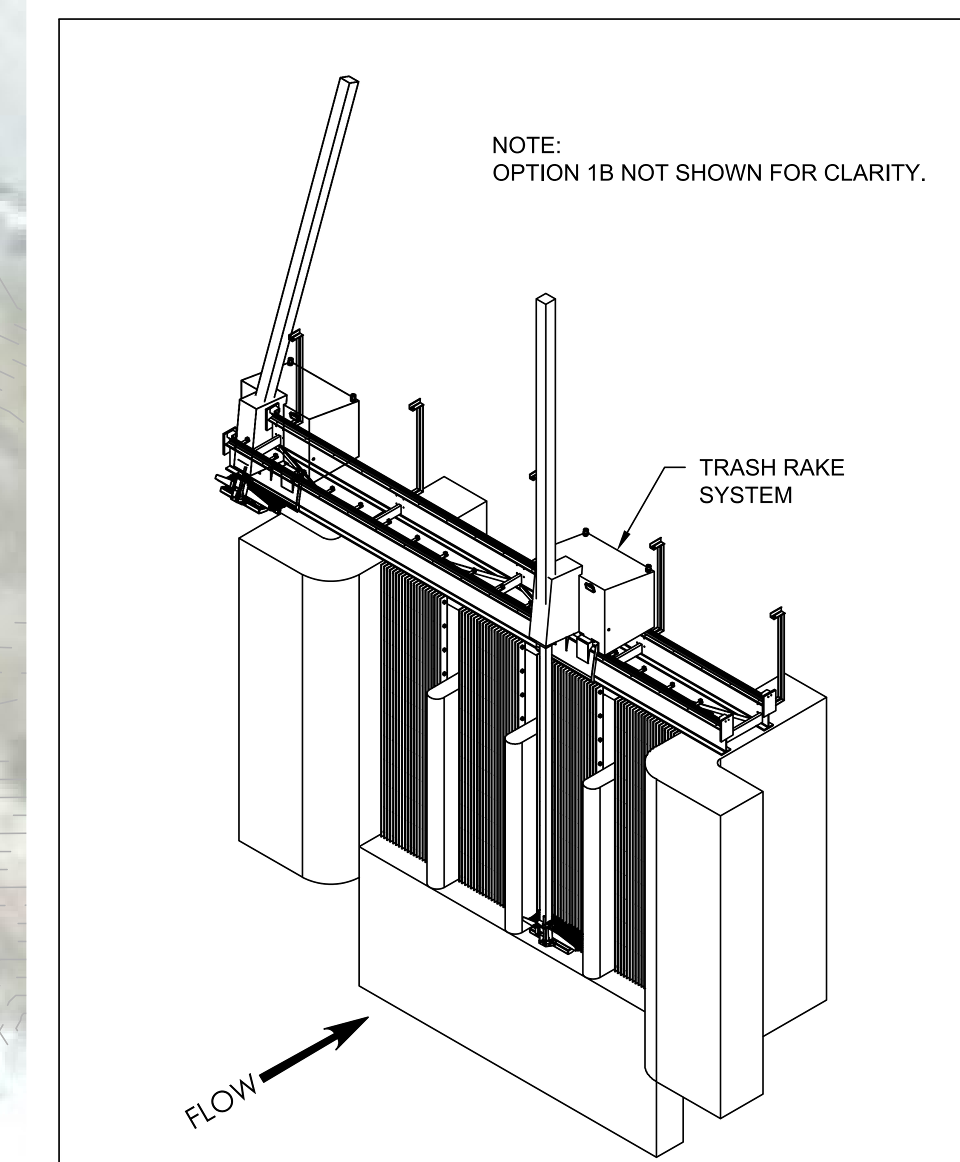
SCALE 1" = 20'-0"

SHEET 01C-ALT3

Appendix H. Trash Rake System Conceptual Layout



A
TRASH RAKE SYSTEM (SECTION VIEW)
SCALE: 1" = 10'



1
TRASH RAKE SYSTEM (ISOMETRIC VIEW)
NOT TO SCALE

HDR

ISSUE	DATE	DESCRIPTION

PROJECT MANAGER	D. MARCH
CIVIL 1	D. MARCH
CIVIL 2	
DRAWN BY	
PROJECT NUMBER	10214954

MONTANA DNRC

DNRC

Broadwater Jetty Improvements

Toston, Montana

2020

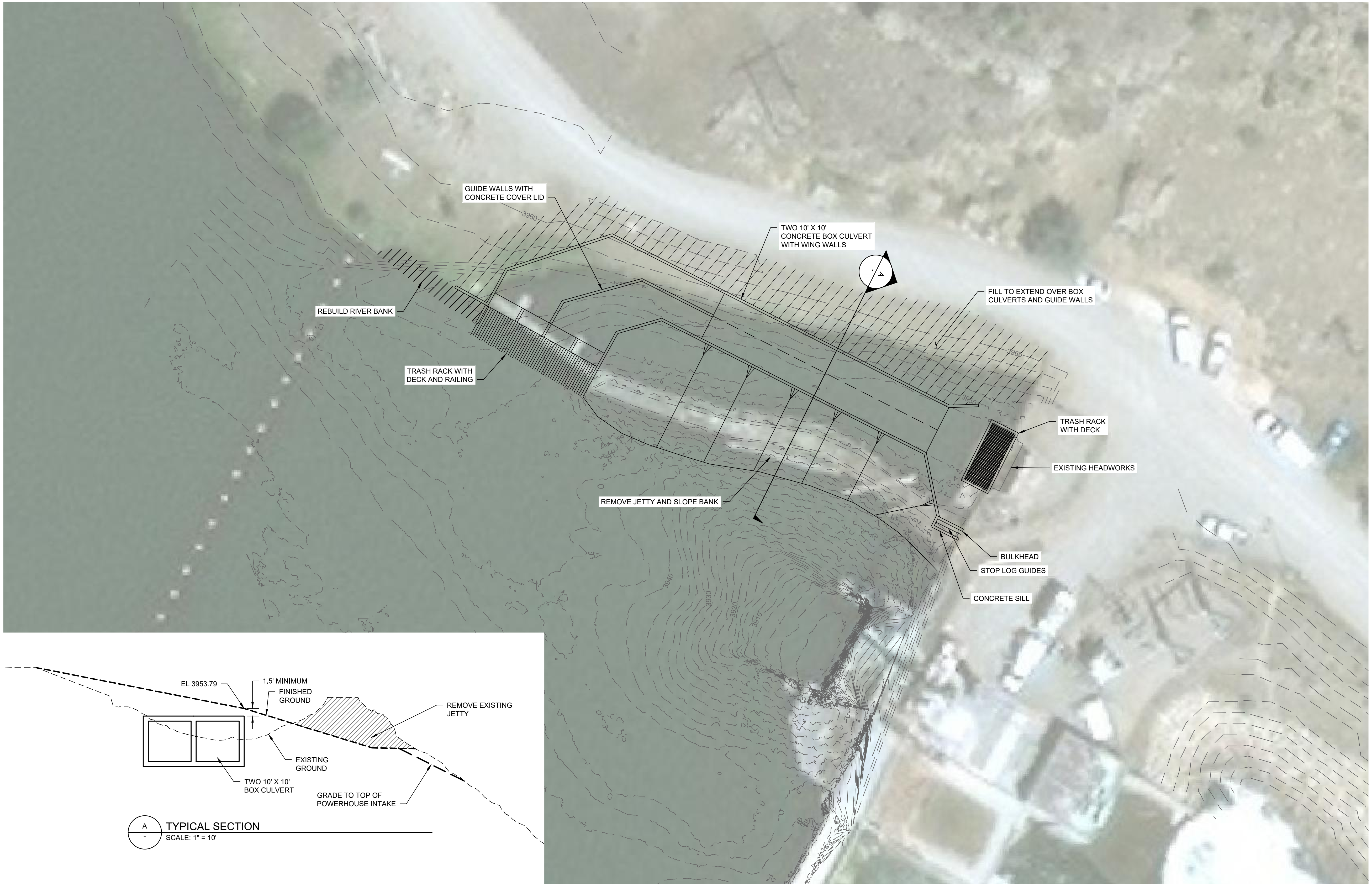
ALTERNATIVE 4
TRASH RAKE SYSTEM

0 1" 2"

FILENAME	01C-ALT4.dwg
SCALE	1" = 20'-0"

SHEET
01C-ALT4

Appendix I. Box Culvert Conceptual Layout



A TYPICAL SECTION
SCALE: 1" = 10'

HDR

ISSUE	DATE	DESCRIPTION

PROJECT MANAGER	D. MARCH
CIVIL 1	D. MARCH
CIVIL 2	
DRAWN BY	
PROJECT NUMBER	10214954

MONTANA DNRC

DNRC

Broadwater Jetty Improvements

Toston, Montana

2020

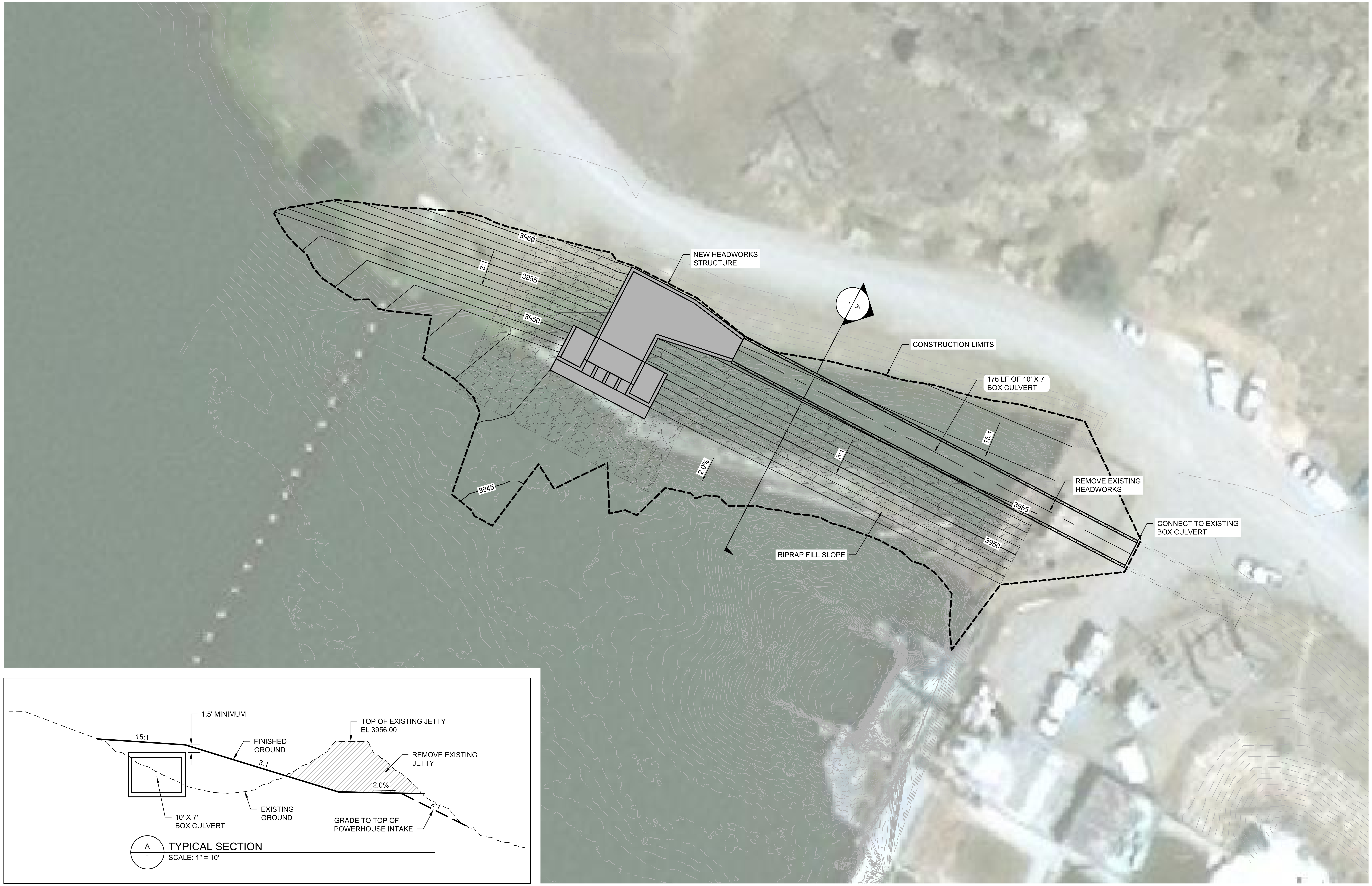
ALTERNATIVE 7
BOX CULVERT

0 1" 2"

FILENAME 01C-ALT7.DWG
SCALE 1" = 20'-0"

SHEET 01C-ALT7

Appendix J. Relocate Irrigation Headworks Upstream Conceptual Layout



A TYPICAL SECTION
SCALE: 1" = 10'

HDR

PROJECT MANAGER	D. MARCH
CIVIL 1	D. MARCH
CIVIL 2	
DRAWN BY	
PROJECT NUMBER	10214954

ISSUE	DATE	DESCRIPTION

MONTANA DNRC

DNRC

Broadwater Jetty Improvements

Toston, Montana

2020

ALTERNATIVE 5
RELOCATE IRRIGATION HEADWORKS UPSTREAM

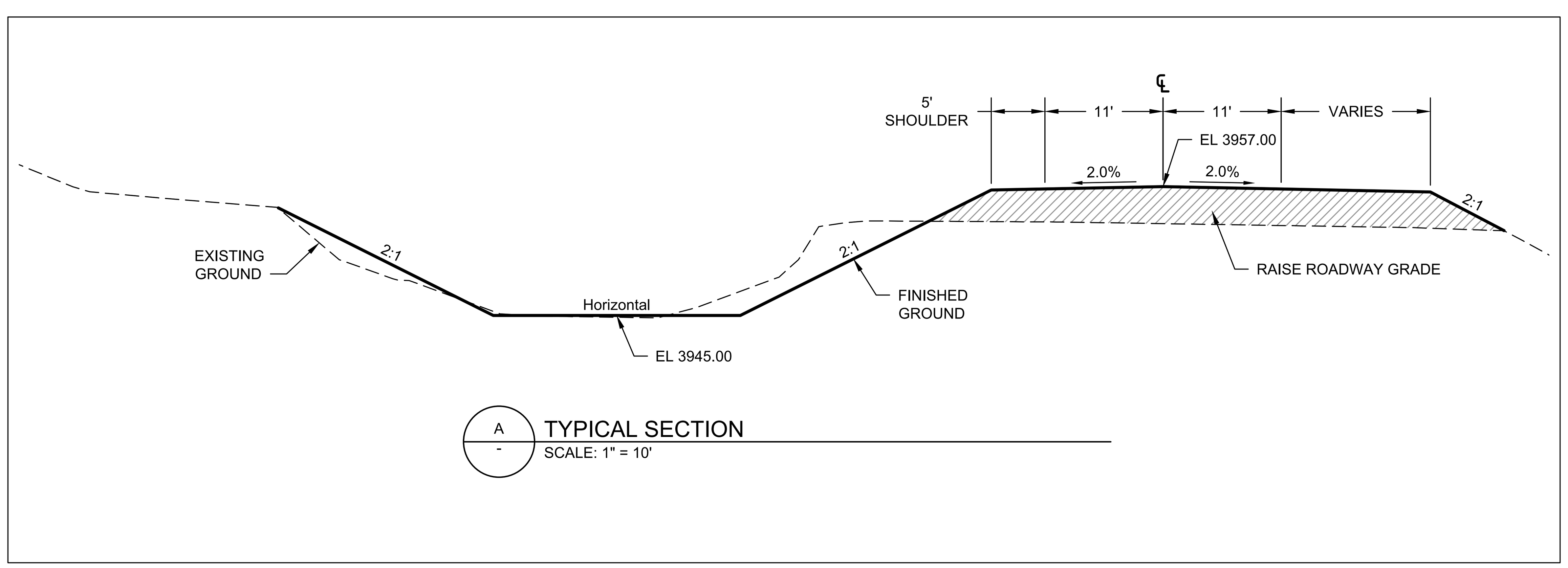
0 1" 2"

FILENAME 01C-ALT5.dwg

SCALE 1" = 20'-0"

SHEET 01C-ALT5

Appendix K. Relocate Irrigation Headworks Downstream Conceptual Layout



A TYPICAL SECTION
SCALE: 1" = 10'

HDR

PROJECT MANAGER	D. MARCH
CIVIL 1	D. MARCH
CIVIL 2	
DRAWN BY	
PROJECT NUMBER	10214954

ISSUE	DATE	DESCRIPTION

MONTANA DNRC

DNRC

Broadwater Jetty Improvements

Toston, Montana

2020

ALTERNATIVE 6
RELOCATE IRRIGATION
HEADWORKS DOWNSTREAM

0 1" 2"

FILENAME 01C-ALT6.dwg

SCALE 1" = 40'-0"

SHEET 01C-ALT6

Appendix L. Bank Stabilization Alternatives Matrix

	Criteria	Definition
1	Operation and Maintenance Requirements	Level of effort to operate and maintain the facilities
2	Recreational and Aesthetic Impacts	Recreational and aesthic impacts due to the facilities, including toward use of the reservoir, access to the reservoir, and campground use
3	Environmental Impacts	Environmental impacts due to the facilities, including towards vegetation growth and wildlife and fish habitat.
4	Geomorphic Susceptibility	Potential for impacts to the functionality or integrity of the facilities due to erosion, instability, and sediment transport/deposition (geomorphic processes)
5	Structure Replacement Frequency	Frequency of structure replacement or major overhauls/refurbishment (structure design life/longevity)
6	Construction Complexity	Complexity of the design and amount of specialty skills and/or equipment required during construction, the extent of work within the reservoir and dewatering requirements, the extent of modifications to existing facilities
7	Construction Cost	Material and labor costs for overall project construction
8	Permitting Requirements	Number of permits required to mitigate impact of construction on the riverine environment
	Criteria	**Definition**
9	Operation and Maintenance Requirements	Level of effort to operate and maintain the facilities
10	Recreational and Aesthetic Impacts	Recreational and aesthic impacts due to the facilities, including toward use of the reservoir, access to the reservoir, and campground use
11	Environmental Impacts	Environmental impacts due to the facilities, including towards vegetation growth and wildlife and fish habitat.

		1 Operation and Maintenance Requirements	2 Recreational and Aesthetic Impacts	3 Environmental Impacts	4 Geomorphic Susceptibility	5 Structure Replacement Frequency	6 Construction Complexity	7 Construction Cost	8 Permitting Requirements			Percent	Rank
1	Operation and Maintenance Requirements		4	3	2	3	5	4	5	1	Operation and Maintenance Requirements	15%	2
2	Recreational and Aesthetic Impacts	2		3	1	3	5	4	5	2	Recreational and Aesthetic Impacts	14%	4
3	Environmental Impacts	3	3		1	3	5	4	5	3	Environmental Impacts	14%	3
4	Geomorphic Susceptibility	4	5	5		5	5	5	5	4	Geomorphic Susceptibility	20%	1
5	Structure Replacement Frequency	3	3	3	1		4	3	5	5	Structure Replacement Frequency	13%	5
6	Construction Complexity	1	1	1	1	2		3	5	6	Construction Complexity	8%	7
7	Construction Cost	2	2	2	1	3	3		5	7	Construction Cost	11%	6
8	Permitting Requirements	1	1	1	1	1	1	1		8	Permitting Requirements	4%	8

Scoring scale:

Rate the importance of the activity in the row relative to activity in the column where they intersect.

If the row is much less important than the column, enter 1

If the row is less important than the column, enter 2

If the row has the same importance as the column, enter 3

If the row is more important than the column, enter 4

If the row is much more important than the column, enter 5

Final Pairwise

		Broadwater Power Project Jetty Replacement and Erosion Control (Jetty Replacement)									
		Operation and Maintenance Requirements	Recreational and Aesthetic Impacts	Environmental Impacts	Geomorphic Susceptibility	Structure Replacement Frequency	Construction Complexity	Construction Cost	Permitting Requirements	Weighted Average	Rank
Alternative	**Alternative Description**	**0.15**	**0.14**	**0.14**	**0.20**	**0.13**	**0.08**	**0.11**	**0.04**	**-**	
Signage and Access Restrictions (Preventative Methods)	Install signage and/or fencing to restrict reservoir activity (e.g., no-wake signs) and/or access along the banks.	5	2	4	3	4	5	5	5	3.91	4
Construct Spur Dikes, Vanes, or Bendway Weirs	Construct vanes, spur dikes, or bendway weirs utilizing rock riprap, precast concrete armor units (CAUs), or other materials to redirect flows.	4	1	3	4	5	1	1	1	2.88	10
Construct Revetment with Rock Ripap, Articulating Concrete Block Mats (ACBMs), or Gabions	Construct a revetment utilizing rock riprap, ACBMs, gabions, or other materials to armor the bank. The revetment could also incorporate vegetation.	5	3	4	5	5	3	2	2	3.97	3
Construct Revetment with Shotcrete or Concrete	Construct a revetment utilizing shotcrete, concrete, fabric or geotextile/geosynthetic formed concrete mattresses, or other materials to armor the bank.	5	1	1	4	4	2	2	2	2.85	11
Construct Riprap Toe Protection with Bioengineered Bank	Construct bank toe protection with rock riprap. Construct a bioengineered bank above the stone toe using soil encapsulated fabric wraps with biodegradable coir fabric.	5	4	4	5	5	3	2	2	4.11	1
Construct Longitudinal Peak Stone Toe with Bioengineered Bank	Construct a longitudinal peak stone toe utilizing rock riprap. Construct a bioengineered bank above the stone toe.	4	4	4	3	3	3	3	2	3.39	5
Construct Bioengineered Bank	Reconstruct the bank as a bioengineered bank utilizing wrapped soil lifts planted with vegetation.	3	4	4	3	3	3	3	3	3.28	7
Revegetate Bank	Protect the bank utilizing a temporary degradable rolled erosion control product (RECP) and revegetate the bank utilizing appropriate plantings and trees.	2	5	4	2	2	4	5	5	3.31	6
Construct Revetment using Native Material	Construct a revetment utilizing boulders, logs, rootwads, or other native materials. Revegetate the bank or construct a bioengineered bank above the revetment.	3	3	5	4	3	2	2	2	3.26	8
No Wake Zone	Move existing barrier upstream and add "No Wake Zone" signage.	5	4	3	3	4	5	5	5	4.04	2
Do Nothing	Leave the current facilities as-is.	3	1	3	1	5	5	5	5	3.05	9

Key:
Scale 1 to 5
1 = Poor/Low Value
5 = Excellent/High Value

Appendix M. Bureau of Land Management Bank Stabilization Recommendations

United States Department of the Interior

BUREAU OF LAND MANAGEMENT
Western Montana District Office
106 North Parkmont
Butte, Montana 59701
http://www.blm.gov/montana-dakotas

04/09/2020

In Reply Refer To:
9100 (LLMTB00000)

EMAIL TRANSMISSION -
Memorandum

To: Courtney Frost, Butte Field Office
Outdoor Recreation Planner (Acting)

From: Casey Trang, Western Montana District
District Engineer

Subject: Toston Dam Bank Stabilization

In response to the ongoing erosion and head cutting along the shoreline of Toston Dam Recreation Site, the Western District Engineering Department is in full support of the partnership between BLM and the Montana Department of Natural Resources Conservation to resolve this issue. Based on our experience with shoreline stabilization and working with internal natural resource partners such as yourself, the WMD Engineering Department recommends the following actions to restore the shoreline and protect it from further degradation:

- Utilize rock revetment by placing stone materials – with a low tolerance for movement – to stabilize the existing bank and restore missing sections of shoreline that have been lost to erosion. Materials that are adequately sized for stream and shoreline protection are strongly recommended. BLM also recommends placement of revetment materials at a minimum of ten feet outside of the existing Toston Dam Recreation Site shoreline. District engineering recommends placing revetment materials at a minimum of 12 inches above the existing river elevation (full pool). It's also recommended that a new bank zone is established and gradually shaped upward to match or tie into the existing line and grade of the existing bank. HDR engineering, which is taking the lead on project design, seems to be well versed in this work and we encourage its input and expertise as to the lines and grades of this material. See Attachment 1 for a site plan showing the area that BLM recommends to be stabilized. Attachment 2 shows a similar project in which a new bank zone was established.

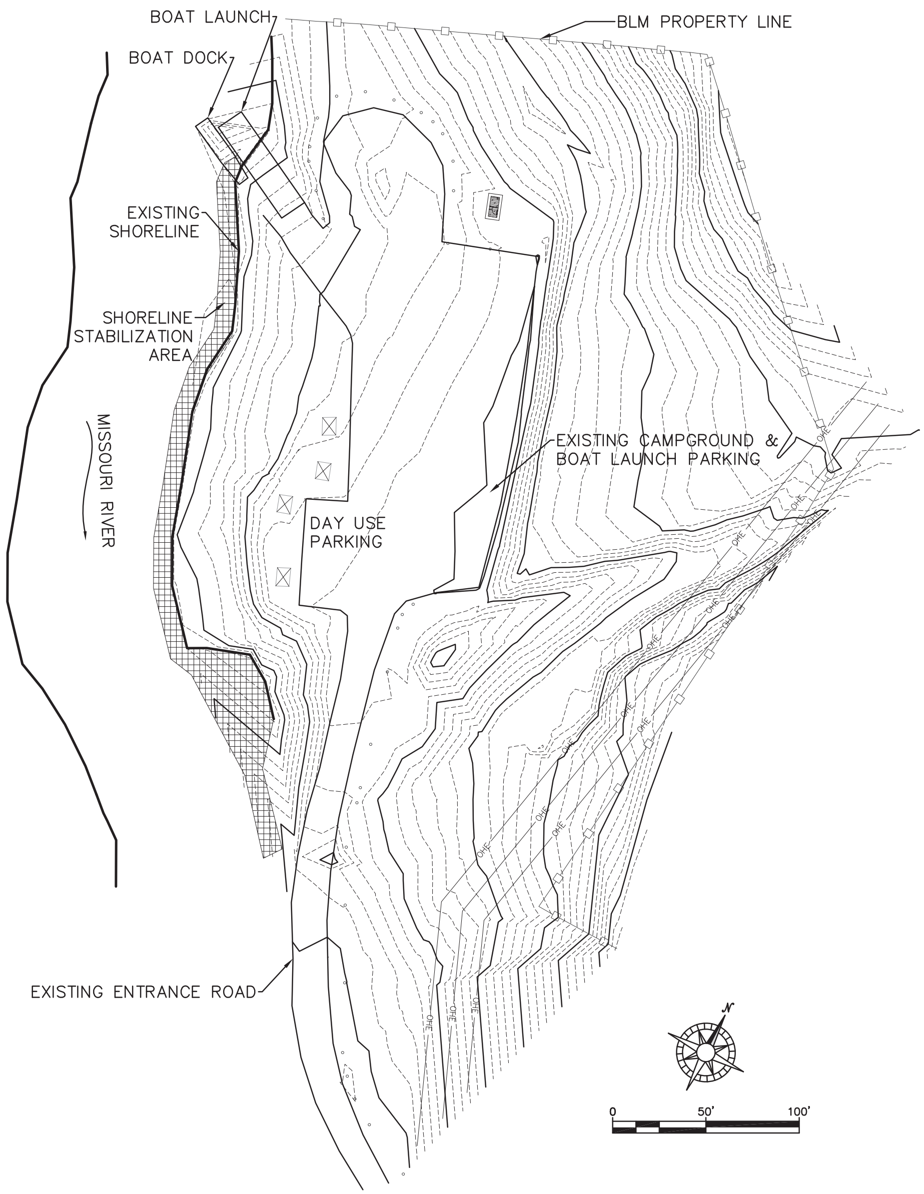
- Cap rock revetment with 6 inches of aggregate base course and compact the material to 95 percent of maximum dry density. Aggregate base material is preferred since it's free draining and easy to shape and compact. The pictures in Attachment 2 show a similar process of a shoreline that was re-established in 2012. This shoreline was not capped with topsoil but the process is consistent with what is proposed by BLM.

- Place and anchor a coyer log fence along the shoreline.

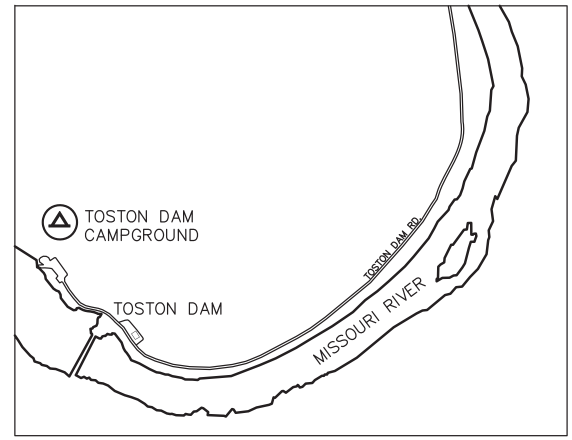
- Cap the aggregate base lift with topsoil and tie directly into the coyer log fence, keying the erosion structure in place. Revegetate the topsoil and coyer fence with hardy, native grasses or comparable materials. This area is generally vegetated with flexible woody stemmed plants such as willows, dogwood, elderberry, and low shrubs when utilizing bio-engineering techniques. Due to the known presence of beaver in the area and the proximity of the adjacent dam, the use of woody stemmed plants should at most, be sparingly used. Alternative vegetation is preference.

Attachments:

Toston Dam Recreation Area Conceptual (1)
Bank Stabilization Photos (4)



LOCATION MAP



LEGEND

- REMOVED PICNIC STRUCTURE
- VAULT TOILET
- FENCE LINE
- OVERHEAD ELECTRIC LINE
- OVERHEAD ELECTRIC LINE

AUTOCAD NAME: Toston_CONCEPT.dwg	MARK	REVISION	DATE	APPROVED
DESIGN OFFICE: WESTERN MONTANA DISTRICT OFFICE				
DESIGNED BY:			X/XX	
DRAWN BY:			X/XX	
CHECKED BY:				
APPROVED BY:				

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

EXISTING GROUND

Upper Toston Recreation Site Renovation

BUTTE FIELD OFFICE — MONTANA

SHEET # OF #


04/24/2012

333D
DEERE
DEERE
05/01/2012


05/02/2012

Appendix N. Final Jetty Alternatives Matrix

Criteria	Definition
Operation & Maintenance Requirements	Level of effort to operate and maintain the facilities
Floating Debris Susceptibility	Potential for impacts to the functionality or integrity of the facilities due to floating debris loading/collection
Geomorphic Susceptibility	Potential for impacts to the functionality or integrity of the facilities due to erosion, instability, and sediment transport/deposition (geomorphic processes)
Impacts to the Dam/Hydropower Intake Risk	Potential for impacts to the hydropower intake due to channel bed instability and material shedding into the channel in front of the hydropwer intake screens and structural risk to the dam
Structure Replacement Frequency	Frequency of structure replacement or major overhauls/refurbishment (structure design life/longevity)
Design & Construction Complexity	Complexity of the design and amount of specialty skills and/or equipment required during construction, the extent of work within the reservoir and dewatering requirements, the extent of modifications to existing facilities
Construction & Life Cycle Cost	50-year present worth, including initial construction cost and level of effort to operate and maintain the facilities
Permitting Level of Effort	Level of effort and number of permits required to mitigate impact of construction on the riverine environment

		1	2	3	4	5	6	7	8				
		Operation & Maintenance Requirements	Floating Debris Susceptibility	Geomorphic Susceptibility	Impacts to the Dam/Hydropower Intake Risk	Structure Replacement Frequency	Design & Construction Complexity	Construction & Life Cycle Cost	Permitting Level of Effort			Percent	Rank
1	Operation & Maintenance Requirements		4	4	3	4	5	1	5	1	Operation & Maintenance Requirements	15%	2
2	Floating Debris Susceptibility	2		4	2	4	4	1	5	2	Floating Debris Susceptibility	13%	4
3	Geomorphic Susceptibility	2	2		2	4	4	1	5	3	Geomorphic Susceptibility	12%	5
4	Impacts to the Dam/Hydropower Intake Risk	3	4	4		3	4	1	5	4	Impacts to the Dam/Hydropower Intake Risk	14%	3
5	Structure Replacement Frequency	2	2	2	3		3	1	4	5	Structure Replacement Frequency	10%	6
6	Design & Construction Complexity	1	2	2	2	3		1	4	6	Design & Construction Complexity	9%	7
7	Construction & Life Cycle Cost	5	5	5	5	5	5		5	7	Construction & Life Cycle Cost	21%	1
8	Permitting Level of Effort	1	1	1	1	2	2	1		8	Permitting Level of Effort	5%	8

Scoring scale:

Rate the importance of the activity in the row relative to activity in the column where they intersect.

If the row is much less important than the column, enter 1

If the row is less important than the column, enter 2

If the row has the same importance as the column, enter 3

If the row is more important than the column, enter 4

If the row is much more important than the column, enter 5

Final Pairwise

	Broadwater Power Project Jetty Replacement and Erosion Control (Jetty Replacement)									
	Operation & Maintenance Requirements	Floating Debris Susceptibility	Geomorphic Susceptibility	Impacts to the Dam/Hydropower Intake Risk	Structure Replacement Frequency	Design & Construction Complexity	Construction & Life Cycle Cost	Permitting Level of Effort	Weighted Average	Rank
Alternative	**0.13**	**0.14**	**0.14**	**0.16**	**0.11**	**0.11**	**0.17**	**0.04**	**-**	
No Action	1	1	1	1	1	5	5	5	**2.29**	**10**
Floating Debris Barrier	1	3	4	4	2	4	4	4	**3.26**	**7**
Floating Breakwater	2	3	4	4	3	4	2	4	**3.15**	**8**
Riprap Jetty	4	4	4	3	5	2	3	2	**3.48**	**2**
FICB Jetty	3	4	4	4	4	2	3	3	**3.44**	**4**
Grout Jetty	3	4	4	4	4	2	3	3	**3.44**	**4**
Pile Jetty	4	4	4	4	5	1	2	2	**3.36**	**5**
Trash Rake System	2	5	3	3	3	3	2	4	**3.01**	**9**
Box Culvert	4	4	4	5	5	3	2	3	**3.77**	**1**
Relocate Irrigation Headworks Upstream	3	4	4	5	5	1	2	1	**3.35**	**6**
Relocate Irrigation Headworks Downstream	1	2	2	4	3	1	2	2	**2.19**	**11**

Key:
Scale 1 to 5
1 = Poor/Low Value
3 = Neutral/Not Applicable/Unknown
5 = Excellent/High Value